# The Journal of Bone and Joint Surgery

*The Official Publication of*
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association
Western Orthopedic Association

SEPTEMBER 1961

American Volume
Vol. 43-A, No. 6

8 THE FENWAY, BOSTON 15, MASSACHUSETTS, U. S. A.
BRITISH OFFICE:
82 PORTLAND PLACE, LONDON, W. 1, ENGLAND

# The Journal of Bone and Joint Surgery

PUBLISHED IN TWO VOLUMES
WILLIAM A. ROGERS, *Editor-in-Chief Emeritus*

AMERICAN VOLUME

*Editor and Chairman* Board of Editors: THORNTON BROWN

American Board of Associate Editors

LENOX D. BAKER, Durham, North Carolina
WILLIAM H. BICKEL, Rochester, Minnesota
DAVID M. BOSWORTH, New York, N. Y.
JOSEPH H. BOYES, Los Angeles, California
JOE B. DAVIS, Portland, Oregon
WILLIAM F. DONALDSON, Pittsburgh, Pennsylvania
ALBERT B. FERGUSON, JR., Pittsburgh, Pennsylvania
CHARLES H. FRANTZ, Grand Rapids, Michigan
HALFORD HALLOCK, New York, N. Y.
CHARLES H. HERNDON, Cleveland, Ohio
JOHN WILLIAM HILLMAN, Nashville, Tennessee
EMANUEL B. KAPLAN, New York, N. Y.
DON KING, San Francisco, California
WILLIAM A. LARMON, Chicago, Illinois
WILLIAM R. MACAUSLAND, JR., Boston, Massachusetts
PAUL E. MCMASTER, Beverly Hills, California
C. LESLIE MITCHELL, Detroit, Michigan
FRED C. REYNOLDS, St. Louis, Missouri
DANIEL C. RIORDAN, New Orleans, Louisiana
WAYNE O. SOUTHWICK, New Haven, Connecticut
O. SHERWIN STAPLES, Hanover, New Hampshire
JACK K. WICKSTROM, New Orleans, Louisiana

BRITISH VOLUME

SIR REGINALD WATSON-JONES, *Editor*

British Editorial Board

H. JACKSON BURROWS, *Chairman*
J. CRAWFORD ADAMS, *Deputy Editor*
W. D. COLTART, *Treasurer*
C. E. L. ALLEN, Cape Town, South Africa
ROLAND BARNES, Glasgow, Scotland
J. S. BATCHELOR, London, England
JOHN CHARNLEY, Manchester, England
F. P. DEWAR, Toronto, Canada
J. KENNEDY ELLIOTT, Wellington, New Zealand
E. MERVYN EVANS, Swansea, Wales
A. L. EYRE-BROOK, Bristol, England
ROGER GARIÉPY, Montreal, Canada
B. KRON-COHEN, Melbourne, Australia
K. I. NISSEN, London, England
DOUGLAS PARKER, Hobart, Tasmania
R. G. PULVERTAFT, Derby, England
H. J. SEDDON, London, England
E. W. SOMERVILLE, Oxford, England
GORONWY THOMAS, Liverpool, England
O. J. VAUGHAN-JACKSON, London, England
PHILIP WILES, Kingston, Jamaica

Corresponding Editors

*Argentina:* JOSÉ VALLS
*Austria:* WALTHER EHALT
*Belgium:* JEAN VERBRUGGE
*Brazil:* F. E. GODOY MOREIRA
*Cuba:* ALBERTO INCLÁN
*Denmark:* JOHANNES MORTENS
*East Africa and the Sudan:* W. H. KIRKALDY-WILLIS
*Finland:* K. E. KALLIO
*France:* R. MERLE D'AUBIGNÉ
*Germany:* MATHIAS HACKENBROCH
*India:* B. N. SINHA
*Italy:* O. SCAGLIETTI
*Japan:* EISHI KONDO
*Mexico:* JUAN FARILL
*Netherlands:* J. D. MULDER
*Poland:* ADAM GRUCA
*Portugal:* ARNALDO RODO
*Sweden:* STEN FRIBERG
*Uruguay:* JOSÉ LUIS BADO

Committees

THE JOURNAL OF BONE AND JOINT SURGERY, INCORPORATED

*The American Orthopaedic Association*

*The American Academy of Orthopaedic Surgeons*

BOARD OF TRUSTEES

KEENE O. HALDEMAN, *Chairman*
R. BEVERLY RANEY, *Vice-Chairman*
H. RELTON MCCARROLL, *Treasurer*
JOSEPH A. FREIBERG, *Secretary*
THORNTON BROWN, *Editor*
H. HERMAN YOUNG
JOHN ROYAL MOORE

*American Society for Surgery of the Hand*
*President:* GEORGE S. PHALEN
*President-Elect:* J. WILLIAM LITTLER
*Secretary-Treasurer:* DON L. EYLER
1919 Hayes Street, Nashville 4, Tennessee

*The Australian Orthopaedic Association*
F. H. MCC. CALLOW, *President*
A. I. RHYDDERCH, *Editorial Secretary*
RICHARD HODGKINSON, *Secretary*, 147 Macquarie Street, Sydney, New South Wales

*The British Orthopaedic Association*
H. J. SEDDON, *President*
SIR REGINALD WATSON-JONES, *Editor*
E. W. SOMERVILLE, *Editorial Secretary*
J. CRAWFORD ADAMS, *Secretary*
47 Lincoln's Inn Fields, London, W.C. 2

*The Canadian Orthopaedic Association*
E. W. EWART, Moncton, *President*
R. G. TOWNSEND, Calgary, *Vice-President*
IAN W. DAVIDSON, *Secretary-Treasurer*
130 Elm Street, Sudbury, Ontario
F. P. DEWAR, *Editorial Secretary*
706 Medical Arts Building, Toronto, Ontario

*New Zealand Orthopaedic Association*
J. KENNEDY ELLIOTT, Wellington, *President*
J. M. SAUNDERS, Wellington, *Secretary-Treasurer*
ALAN ALLDRED, *Editorial Secretary*
475, George Street, Dunedin

*South African Orthopaedic Association*
R. C. J. HILL, *President*
N. M. THOMPSON, *Treasurer*
CYRIL KAPLAN, *Secretary*, 71 Trust Building, Gardiner Street, Durban, South Africa

*Western Orthopedic Association*
*President:* MARVIN P. KNIGHT
*President-Elect:* DON KING
*Secretary:* B. CLYDE HALLEY, JR.,
3707 Gaston Avenue, Dallas 10, Texas

Published in the United States by
The Journal of Bone and Joint
Surgery, Incorporated

Published in the United Kingdom for The British
Editorial Society of Bone & Joint Surgery by E. & S.
Livingstone, Teviot Place, Edinburgh

## THE JOURNAL OF BONE AND JOINT SURGERY

*American Office*
8 The Fenway, Boston 15, Massachusetts, U.S.A.
*Managing Editor:* John A. Reed
*Assistant Editor:* H. Stephen Tilton

*British Office*
82 Portland Place, London, W. 1, England
*Editorial Secretary:* Jean Barnes

# The Journal of Bone and Joint Surgery*

*American Volume*

## TABLE OF CONTENTS

**September 1961**


PAGE

Arthrodesis of the Knee by Double-Plating.
By *Donald B. Lucas, M.D.*, and *William R. Murray, M.D.*, San Francisco, California . 795

A Comparative Study of the Two Popular Methods of Measuring Scoliotic Deformity of the Spine.
By *K. George, M.D.*, and *J. Rippstein, M.D.*, Los Angeles, California . . . . . 809

An Instrument for the Measurement of Oxygen Tension in Bone. A Preliminary Report.
By *Charles F. Woodhouse, M.D.*, Chicago, Illinois . . . . . 819

The Effect of Beryllium on Bone. A Morphological Study of the Progressive Changes Observed in Rabbit Bone.
By *Patrick J. Kelly, M.D.*, *Joseph M. Janes, M.D.*, and *Lowell F. A. Peterson, M.D.*, Rochester, Minnesota . . . . . 829

Radical Exarticulation of the Extremities for the Curative and Palliative Treatment of Malignant Neoplasms.
By *Robert W. Bailey, M.D.*, and *David B. Stevens, M.D.*, Ann Arbor, Michigan . . . . . 845

Some Skeletal Changes in the Ehlers-Danlos Syndrome. A Report of Two Cases.
By *Mark B. Coventry, M.D.*, Rochester, Minnesota . . . . . 855

Carpal Osteochondroma.
By *Kingsbury G. Heiple, M.D.*, Cleveland, Ohio . . . . . 861

Bone Destruction Associated with Aminonucleoside Administration.
By *A. D. Johnston, M.D.*, and *Richard H. Follis, M.D.*, Washington, D. C. . . . . 865


*(Continued on page 3)*

*The Journal of Bone and Joint Surgery* (American Volume) is issued eight times a year—in January, March, April, June, July, September, October, and December. The 1961 subscription price, payable in advance, is $14.50. Single copies $3.00.

*The Journal of Bone and Joint Surgery*, second-class postage paid at Boston, Mass. and at additional mailing offices. Editorial and business offices, 8 The Fenway, Boston, Mass. Accepted at the special rate of postage provided for in the act of February 28, 1925. Paragraph 4, Section 412, Postal Laws and Regulations; authorized April 21, 1932. Additional entry at Concord, New Hampshire, authorized June 10, 1947.

Copyright 1961 by *The Journal of Bone and Joint Surgery, Incorporated*

*TITLE REGISTERED IN UNITED STATES PATENT OFFICE

# *The Journal of Bone and Joint Surgery* WELCOMES ARTICLES WHICH CONTRIBUTE TO ORTHOPAEDIC SCIENCE FROM ALL SOURCES IN ALL COUNTRIES

---

- Articles are accepted only for exclusive publication in *The Journal of Bone and Joint Surgery*.
- Publication does not constitute official endorsement of opinions presented in articles.
- Articles published and their illustrations become the property of *The Journal*.

---

WHEN YOU SUBMIT AN ARTICLE PLEASE SEND:

1. THE ORIGINAL MANUSCRIPT AND, IF POSSIBLE, DUPLICATE MANUSCRIPTS COMPLETE WITH ILLUSTRATIONS. THE EXTRA COPIES WILL GREATLY ACCELERATE EDITORIAL DECISION. Keep a copy. Manuscripts of accepted articles will not be returned.
2. BIBLIOGRAPHY, alphabetical, of references made in text *only*. Please refer to bibliographies in this copy of *The Journal* and follow style exactly.
3. LEGENDS for all illustrations submitted, listed in order.
4. ILLUSTRATIONS
   a. *Black and white glossy prints* of photographs.
   b. *Original* drawings or charts.
   c. *Magnification* of photomicrographs.

NOTES ON PREPARATION OF MANUSCRIPT

- Manuscripts must be typewritten, double-spaced with wide margins.
- Write out figures under 100 except percentages, degrees, or figures expressed in decimals.
- Direct quotations should include exact page numbers on which quotation appeared in book or article.

NOTES ON PREPARATION OF ILLUSTRATIONS

- Number all illustrations.
- Indicate *top* plainly.
- Write author's name on the back of each one.
- Put dates or initials in *Legends*, not on prints.
- Send prints unmounted or mounted only with rubber cement. Paste or glue will damage prints.
- Drawings, charts, and lettering on prints should be done with black India ink. Use white India ink on black backgrounds.
- Make lettering large enough to be read when drawings are reduced.
- When submitting an illustration which has appeared elsewhere give full information about previous publication, credit to be given, and state whether or not permission to reproduce has been obtained.

COPYRIGHT

Material appearing in *The Journal* is covered by copyright. As a general rule permission will be given to reputable medical journals to reprint anything in these pages, if permission is first obtained from *The Journal* and if the material used is properly credited to *The Journal*.

MIMEOGRAPHED BROCHURE. "Writing for *The Journal of Bone and Joint Surgery*" WILL BE SENT ON REQUEST.

Manuscripts submitted for publication in the AMERICAN VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 8 The Fenway, Boston 15, Massachusetts.
Manuscripts submitted for publication in the BRITISH VOLUME should be sent to The Editor, *The Journal of Bone and Joint Surgery*, 82 Portland Place, London, W. 1, England.

# TABLE OF CONTENTS

*(Continued from page 1)*

PAGE

Unusual Bilateral Para-Articular Ossification of the Elbows. Report of a Case.
By *C. L. Jeannopaulos, M.D.*, and *Edward O. Leventen, M.D.*, West Haverstraw, New York ..... 876

Sesamoid Bone of the Subscapularis Tendon. Report of a Case.
By *Avrum Froimson, M.D.*, and *Karl S. Alfred, M.D.*, Cleveland, Ohio ..... 881

Motor Paralysis of the Extremities in Herpes Zoster.
By *B. David Grant, M.B., F.R.C.S. (Edin.)*, and *Carter R. Rowe, M.D.*, Boston, Massachusetts ..... 885

Polyostotic Fibrous Dysplasia Associated with Hyperthyroidism.
By *John P. Kim, M.D.*, and *Shamsher A. K. Khera, M.B., B.S.*, Regina, Saskatchewan, Canada ..... 897

Replacement of the Shaft of the Phalanx with Iliac Bone.
By *George Miyakawa, M.D.*, Charleston, West Virginia ..... 905

Proceedings
The American Academy of Orthopaedic Surgeons: Scientific Sessions ..... 908

News Notes ..... 922

List of Advertisers ..... Adv. 55

Addresses of Contributors ..... Adv. 56

---

*Subscription Rates for 1961*

American Volume, $14.50
Published January, March, April, June, July, September, October, December

British Volume, $7.50
Published February, May, August, November

All subscription rates include postage.

Checks should be made payable to *The Journal of Bone and Joint Surgery, Inc.*

*Microfilms of the American Volumes are available to regular subscribers through University Microfilms, 313 North First Street, Ann Arbor, Michigan*

Although it is intended that all advertising material accepted conforms to ethical medical standards, acceptance does not imply endorsement by *The Journal.*

**THE JOURNAL OF BONE AND JOINT SURGERY**

*American Office*
8 The Fenway, Boston 15, Massachusetts, U. S. A.

*British Office*
82 Portland Place, London, W. 1, England

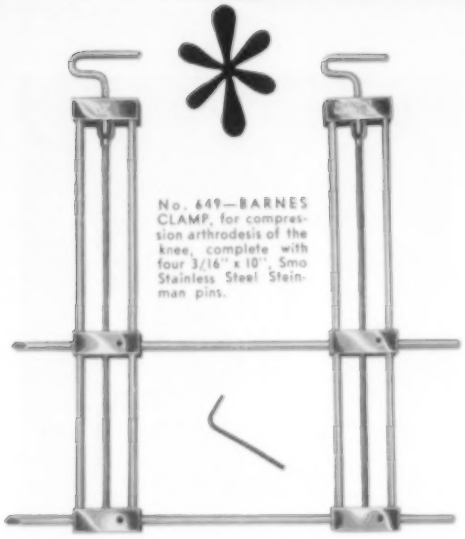
**wright series six** | THE SEPARATE STRUCTURES OF THE HUMAN BODY AND THE COMPARATIVE INSTRUMENTS OF THE ORTHOPAEDIC SURGEON

No. 433-s—INGE RETRACTOR, length 6", depth 1½", Stainless.

## WRIGHT MANUFACTURING COMPANY

880-882 ADAMS AVENUE MEMPHIS, TENNESSEE

WRITE TO DEPT. K-6 FOR FURTHER INFORMATION



No. 649—BARNES CLAMP, for compression arthrodesis of the knee, complete with four 3/16" x 10". Smo Stainless Steel Steinman pins.

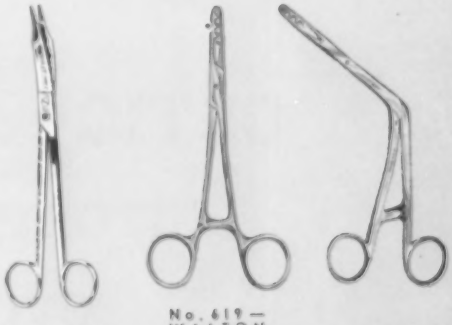
No. 428 — LOWE-BRECK CARTILAGE KNIFE, Stainless.

No. 429 — DOWNING CARTILAGE KNIFE, Stainless.

No. 430 — KNEE SCALPEL, Stainless.

No. 432 — HUNDLEY KNEE KNIFE with removable blade, Stainless.

No. 431 — SMILLIE CARTILAGE KNIFE: center, right or left cuts, Stainless.

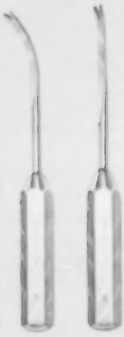


No. 127 — MARTIN CARTILAGE SCISSORS, plain or serrated, Stainless.

No. 619 — WALTON CARTILAGE CLAMP, straight or curved, lengths: 6½" or 8", Stainless.

No. 619-B—WALTON CARTILAGE CLAMP, angular, shaft lengths: 3½" or 5½", Stainless.

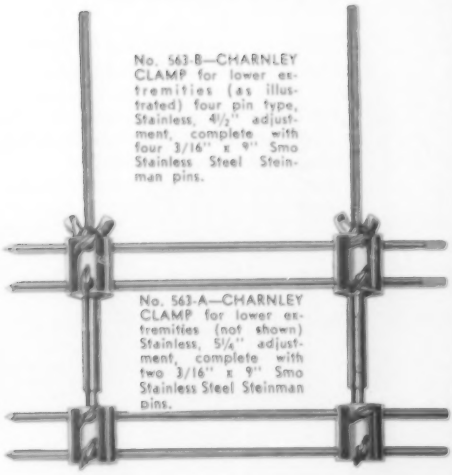
No. 426 — SHERRILL KNEE RETRACTOR, blade depths: 1½", 2" or 2-3/8", Stainless.



No. 606 — BLOUNT KNEE RETRACTOR, Stainless.

No. 637 — McKEEVER CARTILAGE KNIFE, full or medium curve, Stainless.

ALL PRODUCTS OF WRIGHT MANUFACTURING COMPANY ARE OF HIGHEST QUALITY AND ARE UNCONDITIONALLY GUARANTEED AGAINST DEFECTIVE WORKMANSHIP AND MATERIALS.



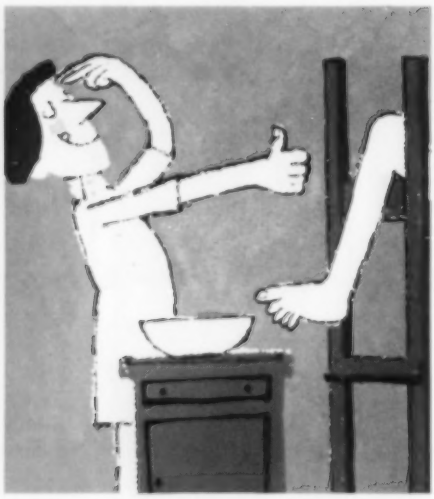
No. 563-B—CHARNLEY CLAMP for lower extremities (as illustrated) four pin type, Stainless, 4½" adjustment, complete with four 3/16" x 9" Smo Stainless Steel Steinman pins.

No. 563-A—CHARNLEY CLAMP for lower extremities (not shown) Stainless, 5¼" adjustment, complete with two 3/16" x 9" Smo Stainless Steel Steinman pins.

WRIGHT

MANUFACTURING COMPANY

880-882 ADAMS MEMPHIS, TENN.



A true artist.....takes joy in his work.....

# **OSTIC** helps you make strong, neat casts every time

**Ostic is the all-around plaster bandage that's so popular in teaching centers. It's easy to use. Applies with a creaminess that's gentle to your hands. Sets quickly, takes hard use.**

Nothing can take the place of professional experience when it comes to building a neat, strong cast. But a good part of your results can depend upon the plaster bandage you use. That's why so many specialists in orthopedic teaching centers use Ostic plaster bandages.

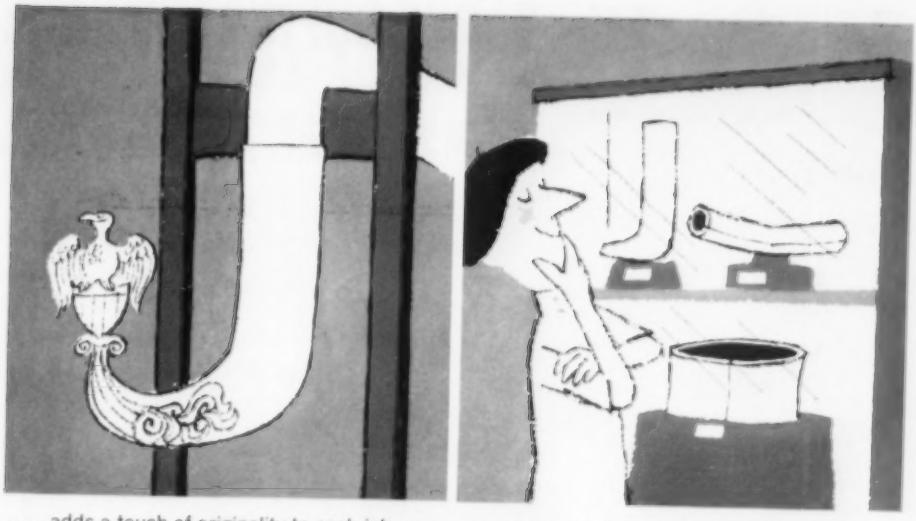
They know they can count on Ostic for consistently fine results. Ostic is fast. It's strong enough to take most any kind of wear. And Ostic delivers at least 97% of the original plaster to the cast. You can work with it all day long.

Each Ostic plaster bandage comes in its own airtight package. Plaster stays fresh indefinitely. Eliminates any danger of presetting.

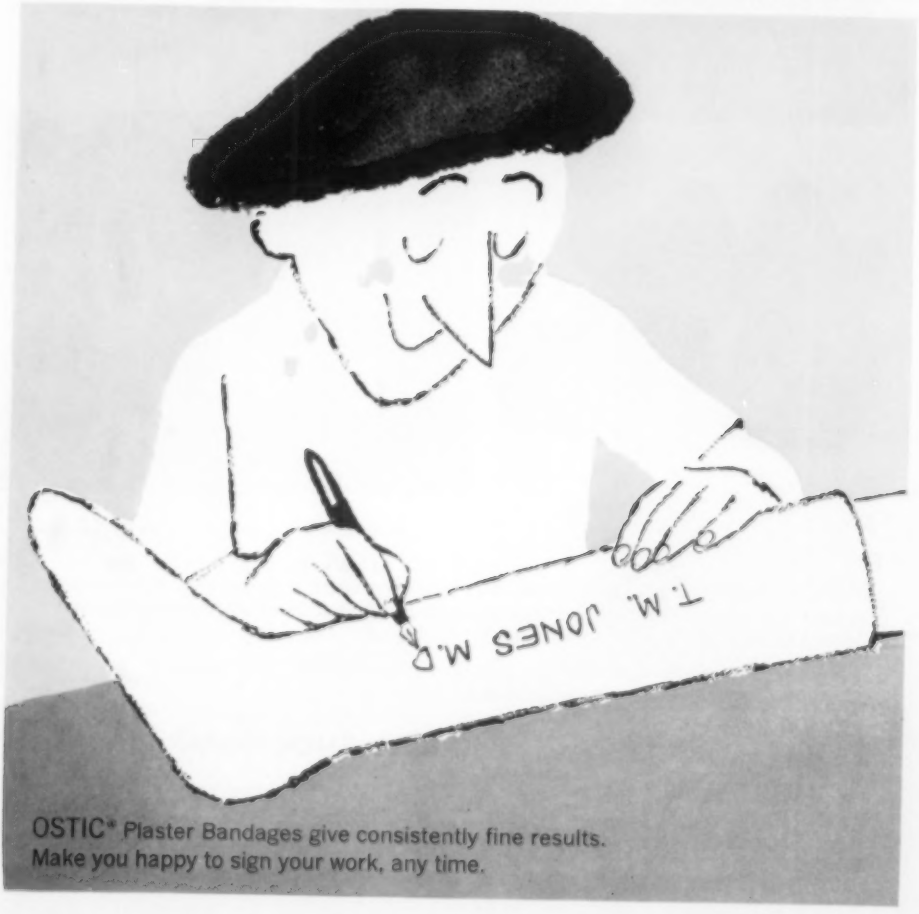
Gentle creaminess of Ostic is never hard on your hands. You get a choice of two setting times: Fast (5 to 8 minutes) and Extra Fast (2 to 4 minutes). Call your Curity representative for the complete story of **OSTIC Plaster Bandages.**

Curity®

THE KENDALL COMPANY
BAUER & BLACK DIVISION

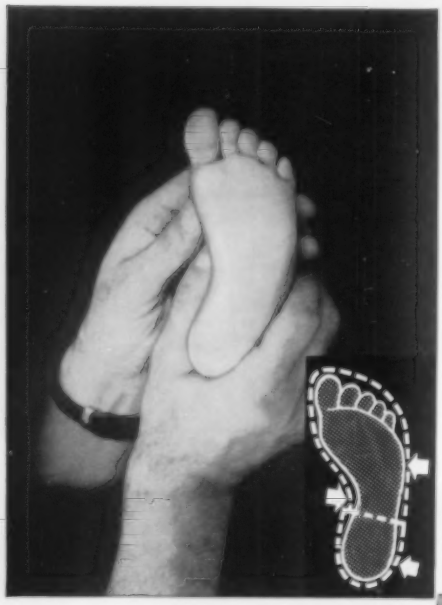


.....adds a touch of originality to each job.....enjoys looking at his masterpieces




OSTIC* Plaster Bandages give consistently fine results.
Make you happy to sign your work, any time.

# the action of the TARSO SUPINATOR SHOE



. . . swings the hind-foot inward, which induces adduction of the fore-foot, elevates the longitudinal arch, and levels the ankle joint.

When the hind-foot is held in a position of inward rotation, the talo-scaphoid and cuneiform-scaphoid joints will remain locked under weight bearing. The arch will not collapse and the ankle will not roll inward.

Correction is accomplished by the specially shaped last. Medially wedged and extended heels promote better weight distribution. Medially extended counters are used for utmost control.

BEFORE AFTER

The Tarso Supinator shoe is used successfully in treatment of the plano-valgus foot. Pronation is controlled at once. Permanent improvements in walking and in foot posture will generally occur. Patients find Tarso Supinators notably comfortable.

Tarso Shoes are ready-made and are available on prescription from dealers in most cities. Write for catalog and name of nearest dealer.

TARSO SUPINATOR REG. U.S. PAT. OFF. SHOE

FOR FLAT FEET

**M. J. MARKELL SHOE COMPANY, INC.**

332 SOUTH BROADWAY • YONKERS, NEW YORK

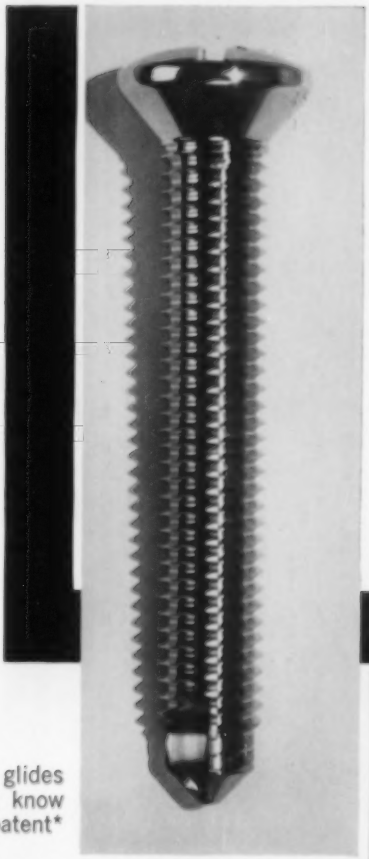
ORIGINATORS OF TARSO PRONATOR® AND TARSO MEDIUS® SHOES

Tarso shoes have been in use for over twenty-five years.



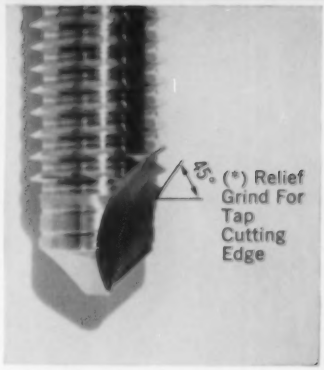
In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

# ● COLLISON BONE SCREW



● **LOOK** for the two **C**'s for the genuine Collison.

● **WHEN** the screw glides into the bone, you know you have a Collison patent* protected screw.




● **FEEL** the smooth rounded burr free threads notable to the sensitive hand of the surgeon.

*The* Collison Surgical Engineering Company ®

SOLE MANUFACTURER OF

COLLISON SURGICAL PRODUCTS

HOpkins 7-4575 3616 FALLS ROAD • BALTIMORE 11, MARYLAND

# when **anxiety and tension** aggravate pain

TABLETS

# Equagesic®

EQUANIL® (Meprobamate, Wyeth) and ZACTIRIN®
(Ethoheptazine Citrate with Acetylsalicylic Acid, Wyeth)

Relieves pain, relaxes mind and muscle

- analgesic action to relieve pain
- calming action to relieve anxiety
- muscle-relaxant action to relieve spasm and tension

## EQUAGESIC RELIEVES PAIN AND ANXIETY

For your patients suffering pain accompanied by anxiety and tension, EQUAGESIC provides gratifying relief. Potent, non-narcotic analgesia is provided by a combination of the potent analgesic, ethoheptazine citrate, with time-proved aspirin. The muscle-relaxant and anti-anxiety effects of meprobamate, coupled with the analgesic agents provide *analgesia in depth.*

These effective agents relieve the painful anxiety and tension of patients suffering from strains, sprains, muscle tension and other musculoskeletal conditions. The comforting pain relief afforded by EQUAGESIC is rarely hampered by side effects.[1,2]

*Satisfactory Pain Relief in 97% of patients with painful musculoskeletal conditions.* In a study[1] of 106 patients suffering musculoskeletal pain associated with anxiety and muscle spasm, EQUAGESIC "... was extraordinarily effective, satisfactory results being obtained in 97% of the patients treated." EQUAGESIC provided effective pain relief for these conditions: osteoarthritis • bursitis • low back syndrome tenosynovitis • whiplash injuries • fractures of small bones • tension headache

*Gratifying Pain Relief in 74% of patients with painful ligament sprains.* In a study[2] of 104 ambulatory cases of acute cervical or lumbar muscle ligament sprain treated with EQUAGESIC, "... control of acute pain was obtained in 74% of the cases." The conditions treated occurred in typical office patients with pain following injuries to the cervical and/or lumbar spine. The author concluded "... EQUAGESIC (Wyeth) is a satisfactory and useful additional tool in the care of the acute injuries due to muscle ligament sprain. ..."

1. Splitter, S.R.: Current Therapeutic Research 2:169 (June) 1960. 2. Harsha, W.N.: J. Okla. State Med. Assoc. 54:12 (Jan.) 1961.

For further information on limitations, administration and prescribing of EQUAGESIC, see descriptive literature or current Direction Circular.

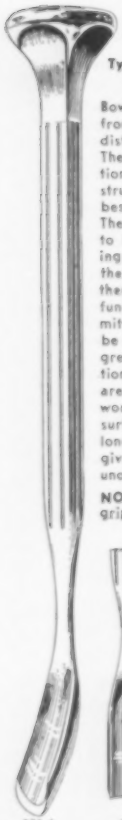
Wyeth Laboratories
Philadelphia 1, Pa.

Wyeth®

# ACCLAIMED BY SURGEONS AS THE LIFETIME INSTRUMENTS

***Because of Their Quality and Durability***

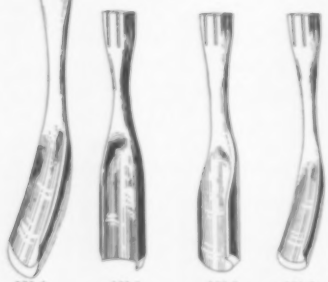
## GOUGES



**Type 440C Stainless Steel—Swedish Hand Forged**

Bowen Gouges, Hand Forged from 44C stainless steel, are of distinctive design and style. The forging method of fabrication produces a fine grain instrument in curves and shapes best desired by the surgeon. The edges are hollow ground to keen razor sharpness resulting in a minimum of effort on the part of the surgeon to make them perform their intended function. The four styles permit a wide range of work to be done. They will be found of great value in bone reconstruction work. The Curved Gouges are particularly adaptable to work in and around contoured surfaces. The fine balance and long square grooved handles give a feeling of sure grip and unobstructed vision.

**NOTE:** Available with finger grips if desired.



103-4 103-1 103-2 103-3

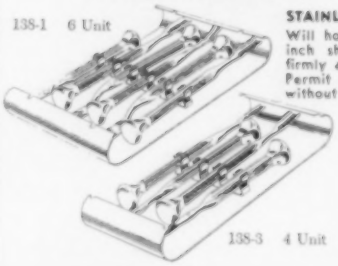
***Consult Your Dealer or Write to:***

**BOWEN & COMPANY, Inc.**

P. O. BOX 5818

BETHESDA, MARYLAND

## INSTRUMENT TRAYS



138-1 6 Unit

138-3 4 Unit

**STAINLESS STEEL**

Will hold any instrument with a ¼-inch shank. Will hold instruments firmly and prevent possible damage. Permit sterilization of instruments without individual handling.

**FEATURES:**

"Four and six unit trays will nest, one on top of the other." "Trays may be placed on end." "Requires less storage space." "Instruments cannot fall out if tray is turned over."

103-5

## HATT SPOON—SPINAL GOUGE

In spinal and arthroplasty surgery, the use of the Spinal Gouge along with our Arthroplasty and Goose Neck Gouges give the surgeon a combination of instruments best suited in this often difficult and intricate work.

**FEATURES:** "Keen cutting edge." "Hardened and tempered to rigid specifications for maximum quality." "Thumb rest handle designed to insure grip and prevent slipping." "Long handles for unobstructed vision."

**No. 103-5** Hatt Spoon—Spinal Gouge.

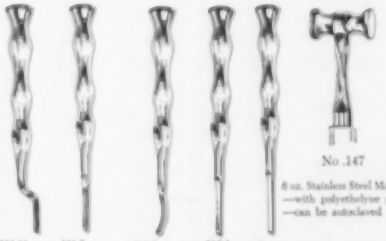
**NOTE:** Available with finger grips if desired.

## CHISELS—GOUGES—OSTEOTOMES

**For Surgery of the Hand**

**Type 440C Stainless Steel—Swedish Hand Forged**

Contoured handles to comfortably fit the fingers of the hand so that holding the instruments will be easy and with a secure feeling. The average overall length of the instruments is approximately 6½ inches. The chisels and osteotomes are available in a goose neck blade such as illustrated below by the goose neck gouge.



No. 147

8 oz. Stainless Steel Mallet —with polyethelyne grip —can be autoclaved

103-10 Goose neck Gouge

101-6 Straight Gouge Straight Edge

103-9 Curved Gouge Round Edge

104-5 Straight Chisel

105-6 Straight Osteotome

# LIBRIUM

**INCREASES MOBILITY**
**ALLEVIATES ANXIETY AND TENSION**
**DECREASES TENDERNESS**

**in skeletal muscle spasticity,** due to spinal cord injury, congenital or acquired brain damage, and other debilitating neuromuscular disorders, such as dystonia and athetosis

**in painful muscle spasm,** associated with myositis, fibrositis, bursitis, tenosynovitis, arthritis, fractures, intervertebral disc syndrome, whiplash injury, low back pain or postural strains

**and whenever emotional disturbances complicate musculoskeletal conditions**
Librium, with its marked muscle-relaxant effect,[1-9] often greatly facilitates treatment in orthopedic patients with musculoskeletal disorders and muscle spasm. When anxiety and tension precipitate or exacerbate musculoskeletal conditions, Librium safely controls the emotional components and, in many cases, simplifies therapy. Response to Librium is more likely when emotional factors are present than when symptoms are entirely secondary to the musculoskeletal disturbances.

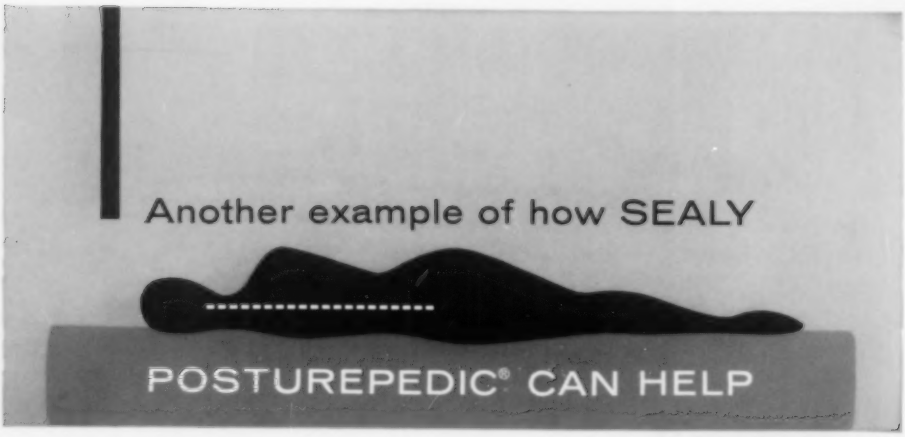
**References:** 1. T. H. Harris, **Dis. Nerv. System,** 21:(Suppl.), 3, 1960. 2. J. Kinross-Wright, I. M. Cohen and J. A. Knight, **ibid.,** p. 23. 3. J. W. Kelley and O. I. Gisvold, **Colorado SP,** 2:3, 1960. 4. I. Hirshleifer, **Curr. Therap. Res.,** 2:501, 1960. 5. H. K. von Rechenberg and H. L. Spiegelberg, **Schweiz. med. Wchnschr.,** 90:1121, 1960. 6. M. Pernikoff, **Clin. Med.,** 7:2313, 1960. 7. W. M. Benson and B. C. Schiele, **Journal-Lancet,** 80:579, 1960. 8. A. Voelkel, **Med. exper.,** 2:170, 1960. 9. A. L. Scherbel, **Am. Pract. & Digest Treat.,** 12:275, 1961.

**Consult literature and dosage information, available on request, before prescribing.**

ROCHE LABORATORIES

LIBRIUM® Hydrochloride—7-chloro-2-methylamino-5-phenyl-3H-1,4-benzodiazepine 4-oxide hydrochloride
Division of Hoffmann-La Roche Inc.

**Taut muscles & tense emotions**




**CASE 262**

My husband developed a most severe case of rheumatoid arthritis. The pain and aching is unbearable in his spine. I decided to try a Sealy Posturepedic for him. Nothing helped my husband's back like his Posturepedic in making him comfortable during these attacks in his back.

*(Excerpt of letter from Mrs. J. B., Jr., Trenton, N. C. Name available on request.)*

You know that chronic lower back trouble is not a simple matter. The Posturepedic mattress, then, cannot be a "cure." But patients who have tried Posturepedic and doctors who use it, too, know it *can help*. They find the firm, level support Posturepedic gives to spine and muscular system in back and limbs promotes normal, healthful sleep among *all* persons.

The Sealy Posturepedic, as you undoubtedly know, is designed in cooperation with leading orthopedic surgeons. We believe your investigation and *personal use* will firmly convince you of its distinctive benefits and, we would hope, merit your valued recommendation. Why not prove it to yourself by taking advantage of this liberal professional discount plan now?

**We invite you to take advantage of a professional discount**

This is a saving of $39 per set over the regular retail price for innerspring mattress and matching foundation. Limit: one full or two twin size sets. MAIL TO: Sealy Mattress Co., 666 N. Lake Shore Dr., Chicago 11

☐ Enclosed is my check. Please send the Sealy Posturepedic set(s) indicated below.

☐ 1 Full Size
☐ 1 Twin Size ☐ 2 Twin Size

☐ Please send me additional information about professional discounts on Sealy Posturepedic mattresses.

| | Retail | Professional |
|---|---|---|
| Posturepedic Mattress each $79.50 (add state tax) | | $ 60.00 |
| Posturepedic Foundation each $79.50 (add state tax) | | $ 60.00 |
| Posturepedic in Foam Rubber $159.00 per *set* (add state tax) | | $120.00 |

G9

*Dr*_____

*Residence*_____

*City*_____ *Zone*_____ *State*_____

SEALY, INC., 666 N. LAKE SHORE DRIVE, CHICAGO 11, ILLINOIS

©Sealy, Inc., 1961

# A NEW SYSTEM FOR HANDLING PATIENT TRANSFERS WITHIN YOUR HOSPITAL

Stryker

PORTABLE WHEEL STRETCHER

★ Lifting is made easy

★ Patients are comfortable at all times during movement

★ Possibility of post-accidental injury is reduced

★ Folding feature permits quick, easy storage in a minimum of space

No more litter changes . . . No more delays. This versatile new Stryker Stretcher handles your patient transfers in one smooth, efficient operation. Patient and stretcher are lowered onto a portable folding base and remain there, even during examination and X-ray!

Light weight aluminum construction (unit weighs only 29 lbs. complete), locking casters, and corner handles make it easy to move from place to place. Waterproof nylon cover gives comfortable support without pad.

***See how easily this new Stryker Stretcher solves your patient handling problems. Ask for one on 30 day trial.***

Stryker Orthopedic Frame Company

420 ALCOTT STREET • KALAMAZOO, MICHIGAN

# HemoVac closed suction aids in completing successful surgery

PAT. PENDING

Improves and speeds healing by gently pulling wound tissue together by suction . . . draws excess fluids and dead cells completely out of the wound area. May be applied for irrigation or closed circulation of anti-biotics to treat osteomyelitis and potentially infected wounds.

HemoVac goes to work as soon as deep fascia has been closed . . . continues without interruption, even while patient is transferred to recovery room. Completely portable and disposable.

**THE HEMOVAC PRINCIPLE**

is simple and logical. The multi-perforated section of non-pyrogenic plastic tubing (⅛" diameter) is laid in the wound at the point(s) where blood and lymphatic fluids are prone to collect and led out through sound tissue away from the wound area. After proper wound closing the HemoVac Spring Evacuator Pump maintains a constant and gentle suction, removing excess fluids and drawing separated tissues together for faster healing. Thus all wound tissue is permitted to heal more rapidly and naturally.

Write for new illustrated brochure

zimmer®

Developed and manufactured by Snyder Mfg. Co., Inc., New Philadelphia, Ohio

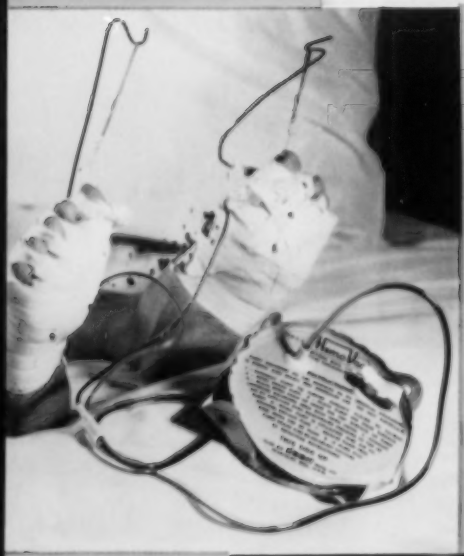
Distributed exclusively by Zimmer Manufacturing Co., Warsaw, Indiana, U.S.A.

QUALITY • SERVICE • RESEARCH

No post-amputation fever. Minimal pain. Nice primary wound healing.

No visible stain even 40 hours after operation.

HemoVac kept wound clean, flat and free of seepage.



# zimmer®

Keller procedure (bunion) With Y connector, Evacuator handles both wounds.

First day after bone graft. Note lack of swelling around toes.

Easily portable unit allows earlier ambulation.

*Precise Positioning and Positive Fixation—*

*with* AMERICAN-Albee

ORTHOPAEDIC *and* FRACTURE TABLE

● Acknowledged as the most versatile in its field, the American-Albee Orthopaedic and Fracture Table enables the orthopaedic surgeon to achieve "perfect positioning" of short, tall, obese and even infant patients . . . easily and rapidly. It is designed to accommodate closed fracture reductions as well as the increasing demands of complex orthopaedic surgery. Thus, to orthopaedists the world over, the name American-Albee identifies the table of choice for this comprehensive branch of medicine.

Ideal complement to this improved table is the American DV-22 Major Surgical Light . . . a new concept in easily maneuverable illumination . . . cool, shadowless, color-corrected . . . intensity to 10,000 foot candles from a dual source.

● *Write for Fracture Table Brochure TC-100R and Major Light Catalog LC-121R.*

AMERICAN STERILIZER

ERIE • PENNSYLVANIA

# NEW *Richards* EBONIZED STAINLESS FINISH STOPS REFLECTED GLARE

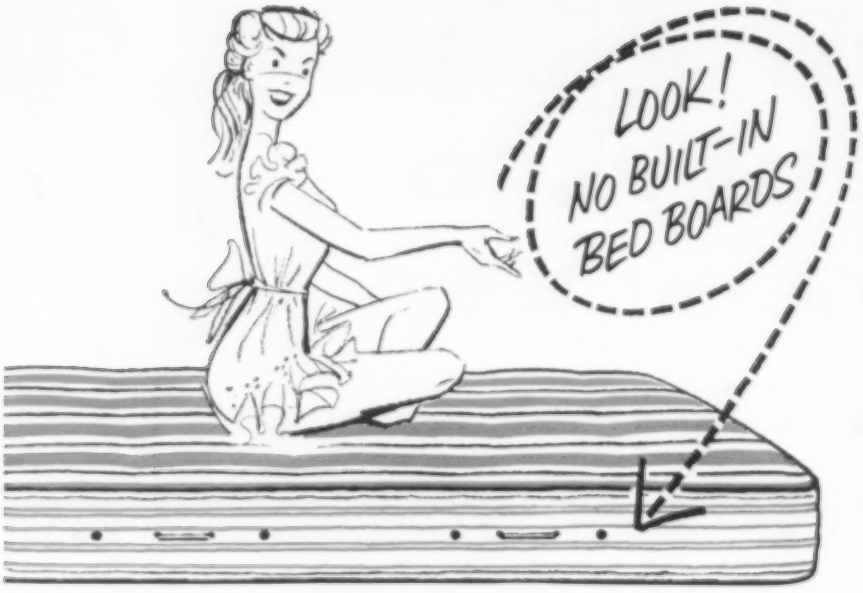
Now **ebonized stainless** — another product of Richards research — increases the working efficiency of surgical instruments. The finish, a dull ebony color, contrasts sharply with light tissue tones . . . and does not reflect glare from brilliant overhead spotlights. This heightened contrast brings the contour of instrument against operative area into clear focus — reduces eyestrain and fatigue, increases operating speed, ease, and efficiency.

Richards unique finishing process removes impurities from the pores of the metal and assures permanence. Repeated autoclaving will not affect the finish in any way.

*Richards* MANUFACTURING COMPANY

For full details, write:

756 Madison Avenue Memphis 3, Tennessee




# *Aireloom* INVENTS A NEW MATTRESS THAT NEEDS NO BUILT-IN BEDBOARDS

**VITAGENIC**—the prescription-built extra-firm mattress eliminates the need for old-fashioned built-in bedboards. That's because VITAGENIC is made right! Many mattresses are structurally weak, basically inadequate and require the addition of a makeshift board to strengthen them. VITAGENIC stands alone as the first *true* therapeutic mattress for pain of backache or sacroiliac injury.

**VITAGENIC**—the prescription-built extra-firm mattress—*offers curled hair for resilient firmness!* Your patients get the benefit of firm body support without undue stress on nerve points or interference with circulation. VITAGENIC also guarantees *hand-stitched sidewalls that do not sag!* Your patients are able to get in and out of bed with less effort and greater stability because VITAGENIC's sag-free sidewalls allow no "give" that might upset your patient's equilibrium. This means *12% more usable sleeping surface* and is only achieved by meticulous hand-stitching.

**VITAGENIC**—the prescription-built extra-firm mattress, is a mattress and box spring combination made *exactly* to the specifications of registered orthopedic specialists. With VITAGENIC, there can be no doubt your patient is resting correctly and comfortably. *You* prescribe the optimum degree of firmness necessary as well as other features important for your patient's treatment.

***THE VITAGENIC IS GUARANTEED IN WRITING FOR FIFTEEN YEARS!***

**For full details on the extra-firm prescription-built VITAGENIC, contact**

*Aireloom* **BEDDING COMPANY**

1119 Westminster Avenue, Alhambra, California
*created by King Karpen — established 1951*



In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

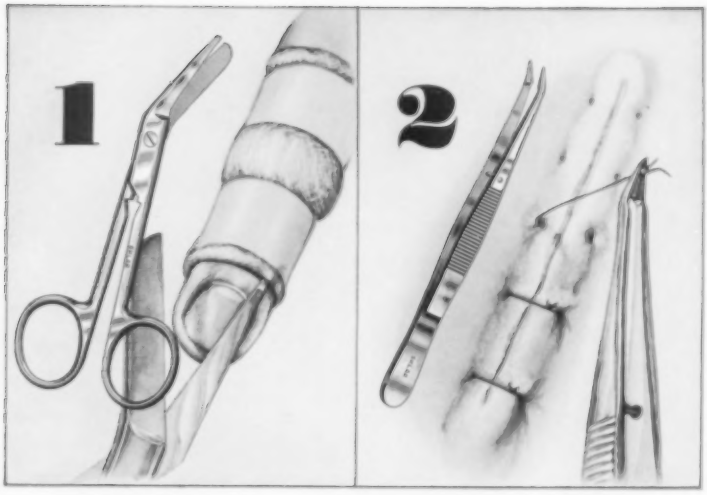
# A NEW APPROACH TO FOOT COMFORT . . . *

PROGRESS REPORT
ON SHOES AND LAST DESIGN
BASIC SHOES FOR MEN AND BOYS
Rx Alden Pedic's Purposes:
1. Fit the individual foot's shape . . .
2. Accommodate prescribed corrections and instructions . . .
3. Provide a stable, controlled foundation.

*

The nation's foremost foot-fitting specialists use Alden-Pedic Shoes.
*Write today for . . .*
OUR SHOE PROGRESS REPORT . . .

*The Key to*
C. H. ALDEN SHOE CO. BROCKTON, MASS.
*Foot Balance*




# specifically designed for the purpose

## 1 Burnham Finger Bandage Scissors

Minimizes pain caused by conventional acorn tip ...thin lower blade with rounded tip slips easily under bandage... notched shank facilitates ready removal of needles frozen to syringes...provides leverage to shear through heavy dressings — yet compact and light enough for the pocket.

## Healy Suture Removing Forceps 2

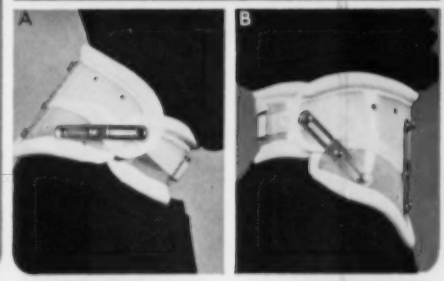
Superior to anatomic forceps for suture removal... broad triangular shaped jaws... roughened inner surfaces grip and hold the suture for cutting...precisely aligned, pointed tips permit gentle teasing out of suture ends that have retracted under the skin or become encrusted with exudate.

SKLAR PRODUCTS

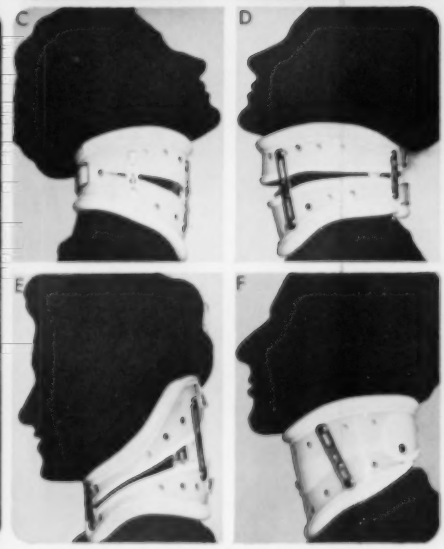
*Both instruments precision made of stainless steel by SKLAR, Long Island City, N.Y.*

Available through accredited surgical supply dealers.

LIGHT WEIGHT · WASHABLE · ADJUSTABLE




CERVICAL COLLARS FOR EXTENSION-FLEXION OR STABILIZATION




A & B **THE EXTENSION-FLEXION COLLAR** — A universal cervical collar, extremely versatile and adaptable for extension, flexion, or stablization.

C **The MYO-VENT** A one-piece extension collar with ventilated adjustability.

D **The CER-VENT** Extension Model. A one-piece collar with ventilated adjustability. Easy to put on, complete support.

E **The CER-VENT** Flexion Model. A one-piece collar with ventilated adjustability. Easy to put on, complete support.

F **The MYO-CERVICAL** A one-piece extension collar with overlapping adjustment.

Catalog and Order Blanks upon request.

*** FLORIDA BRACE CORP.**

**601 Webster Avenue « » Post Office Box 1366**
**Winter Park 3, Florida, Telephone Midway 4-2650**

# 3 vital considerations in relief of pain and restoration of function in hip pathology

## Election of Arthroplasty

"Artificial prostheses for replacement of the upper end of the femur deserve a place in our armamentarium of treatment of hip disease."[1]

## Choice of **Vitallium**®

"We believe that the cobalt-chrome alloys [VITALLIUM] have in clinical experience proved to be so superior in all respects to the existing stainless steels that they should now be very seriously considered for all surgical implants."[2]

## Selection of Prosthesis

"... the Austin Moore intramedullary VITALLIUM prosthesis [is] one of the best prostheses available at the present time."[3]

**Advantages of Hip Arthroplasty:**

- Pain and disability relieved in most cases
- Shorter hospital stay; briefer convalescence period
- Less nursing care required
- Secondary surgical procedures unnecessary in virtually all cases
- Return to active, useful life

**Indications for Hip Arthroplasty:**

| | |
|---|---|
| Osteoarthritis | Acute tractures in the aged |
| Rheumatoid arthritis | Un-united, long-term fractures |
| Aseptic and avascular necrosis | Delayed non-union |
| Bilateral ankylosis | Acute unstable fracture (Pauwels' 3) |
| Salvage | Pathologic fractures |

For further information about VITALLIUM appliances, consult your surgical dealer or write to Austenal Company.

**REFERENCES:** 1. Gaensler, F.G.: Wisconsin Med. J. 59:181, 1960. 2. Scales, J. T., and Zarek, J.M.: J. Bone & Joint Surg. 37B:527, 1955. 3. Matchett, F.: Rocky Mountain M.J. 56:47, 1959. 4. Callahan, J.J.: S. Clin. North America, W.B. Saunders Co., Philadelphia, Feb. 1957, p. 135.

# What is **Vitallium**®?

VITALLIUM is a registered trade mark of the Austenal Company applied to certain cobalt-chromium alloys and to surgical appliances made from those alloys.

"[Its] unique suitability for surgical appliances derives from its inherent corrosive resistance, its compatibility with human tissues, its inertness and lack of electrolytic activity, together with its toughness and strength."[4]

Due to the toughness of the alloys, VITALLIUM appliances are not readily machined or worked by conventional methods. Special equipment designed by Austenal is used, thereby maintaining rigid specifications in all manufacturing procedures.

Twenty-five years of experience in machining and casting of VITALLIUM permits the versatile fabrication of many intricate designs necessary to conform to the anatomical requirements of the human skeletal structure.

Constant evaluation of raw materials, processes utilized, metallurgical knowledge and rigid inspection procedures insure the highest quality-control standards for surgeon-approved VITALLIUM products.

**With over 9 million VITALLIUM surgical implants in use, not a single case of corrosion has been reported in the literature.**

# VITALLIUM®

***Pioneer and leader in corrosion-resistant surgical alloys***

25th year

AUSTENAL COMPANY SURGICAL PRODUCTS

Division of Howe Sound Company • 224 East 30th Street, New York 16, N. Y.

# CAMP
# HIP ABDUCTION PILLOW

***effective therapy at home***

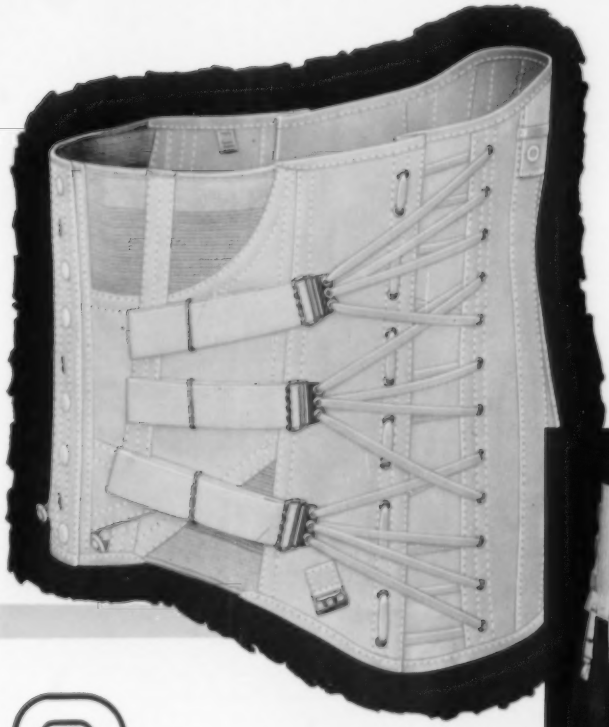
An abduction pillow splint is a practical, atraumatic method for gradually obtaining hip abduction in infants with abduction contractures, unilateral or bilateral hip dysplasia and many cases of congenital dislocation. It is also an effective means of maintaining abduction following more severe dislocations requiring rigid immobilization or surgery. This type of pillow splint is well tolerated, permits the child to sit or stand while maintaining the abduction position.

In addition to the Camp regular Frejka type pillow this new, improved Camp pillow splint fits the contour of the legs to bring the child to froglike position. Adjustable for leg size; a plastic water resistant pillow held in a pocket of the bib; crossed adjustable shoulder straps, all with gripper snap fasteners for easy application. Bib is made of a soft attractive cotton fabric and extra bibs are available for use while one is being laundered. This permits treatment without interruption.

Three sizes (pillow width between legs) —Small 6", Medium 9", Large 12".

S. H. CAMP & COMPANY, JACKSON, MICHIGAN

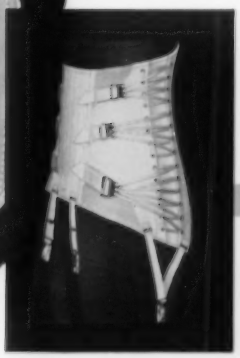
S. H. Camp & Company of Canada, Ltd., Trenton, Ontario



DEEP BACK SACRO-LUMBAR SUPPORT BY TRUFORM.

Men's Model 445-EHS (left) has 4 removable steel back stays.

Women's Model 1107-HS (below) has 2 steel stays.



# 3 SETS OF PULL STRAPS PROVIDE RIGID SUPPORT

**A great degree of rigidity can be secured with the deep-front sacro-lumbar garment pictured above . . .**

- Removable semi-rigid stays in the back control antero-posterior flexion.
- 3 sets of pull straps operate through the side lacing to control traction.
- Deep front for greater rigidity, elastic top and bottom gussets for more comfort.

Always rely on Truform supports that are anatomically correct and therapeutically sound. Rely, too, on fitting by expertly trained and skilled technicians. Prescribe *Truform anatomical supports* with confidence . . . available to you and your patients only from the Ethical Appliance Dealer.

TRUFORM

***anatomical supports***

3961 Rosslyn Drive, Cincinnati 9, Ohio

Branches: New York and San Francisco



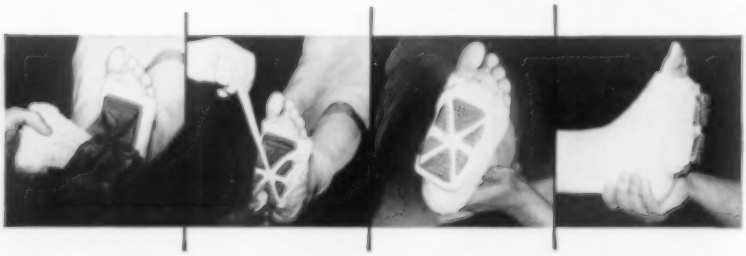
In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

## *A significant new development in walking heel design!*

Introduced in response to numerous requests from the medical profession for a lower, more comfortable walking heel for ambulatory cast patients, and one which could be anchored in the cast more securely. The F. B. CAST CUSHION is the result of extensive research, experimentation and clinical testing and brings you these many long awaited advantages.

*De Puy*

# F. B. CAST CUSHION



**Easier to apply and anchor more securely** than conventional walking heels. Deep criss-cross section spacing permits the plaster bandage to be applied as a normal figure eight wrapping as illustrated. Raised tips on inner side of CAST CUSHION set firmly in cast to prevent lateral movement.
**Lower for greater patient comfort** and elimination of forced limp...a true walking aid, not a stilt.
**Molded of fine quality rubber...** strong and long wearing, yet sufficiently resilient to provide adequate cushioning and shock absorption. No-slip, no-mar tread.
**Order a supply today...** No. 845, $15.00 per dozen.

**DePuy Manufacturing Co., Inc., Warsaw, Indiana**




In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

# Put your low-back patient back on the payroll

*Soma relieves stiffness —stops pain, too*

**YOUR CONCERN:** Rapid relief from pain for your patient. Get him back to his normal activity, *fast!*

**HOW SOMA HELPS:** Soma provides direct pain relief while it relaxes muscle spasm.

**YOUR RESULTS:** With pain relieved, stiffness gone, your patient is soon restored to full activity—often in days instead of weeks.

Kestler reports in controlled study: *Average time for restoring patients to full activity: with Soma, 11.5 days; without Soma, 41 days. (J.A.M.A. Vol. 172, No. 18, April 30, 1960.)*

Soma is notably safe. Side effects are rare. Drowsiness may occur, but usually only in higher dosages. Soma is available in 350 mg. tablets. **USUAL DOSAGE:** 1 TABLET Q.I.D.

*The muscle relaxant with an independent pain-relieving action*

**SOMA®**

*(carisoprodol, Wallace)*

Wallace Laboratories, Cranbury, New Jersey

What a difference

a sole makes . . .

especially if it's

Alden-Pedic

Exclusive Foot-Balance® Shoe

with *RIPPLE®

Bantam-Rib Sole

Lighter, springier-than-ever, this new bantam version of the RIPPLE® Sole puts a resilient cushion between your patient's foot and hard floors and pavements. Absorbs shock, adds spring to the step. Gives excellent traction. And, because they're Alden-Pedics, you'll know that they're scientifically designed to FIT . . . both your prescribed corrections and your customer's feet.

*For futher information on SHOES, write:*

C. H. ALDEN SHOE COMPANY, BROCKTON, MASS.

*For free RIPPLE® Sole folder, write:*

RIPPLE SOLE CORPORATION

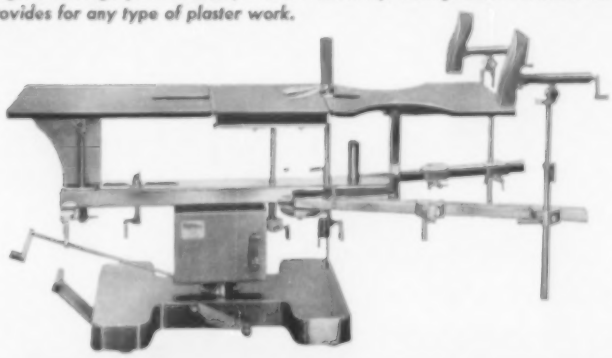
557-U Mutual Building - Detroit 26, Mich. *TM Ripple Sole Corp.

Model 3000

ORTHO-TRAC

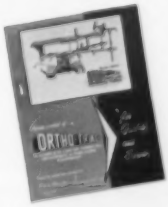
ORTHOPEDIC and SURGICAL TABLE

*. . . designed to handle every type of orthopedic surgery as well as a great deal of general surgery. In addition, it is the finest hip nailing table available and provides for any type of plaster work.*



**CHECK THESE EXCLUSIVE FEATURES**

- Hydraulic foot control positions table height.
- Convenient control crank permits position variation from 18° Trendelenburg tilt to 17° reverse Trendelenburg tilt.
- Entire table, including table top, electrically conductive throughout.
- Durable stainless steel base easy to clean, keep clean.
- Doctor Clayton Foot Plates conform anatomically and allow better positioning and tie for holding the foot.
- A.P. Cassette Tunnel takes any size X-ray film used for hip nailing . . . moves laterally, either way, for unexcelled accessibility to the hip.
- Built-in facilities accommodate grid for A.P. views. Grid is available as an accessory.
- All tube endings closed with metallic inserts.



***Complete Information On Request***—20-page booklet complete with data and application photos available on request.

*Another product of* ORTHO-TRAC *a complete line of hospital orthopedic and fracture equipment.*

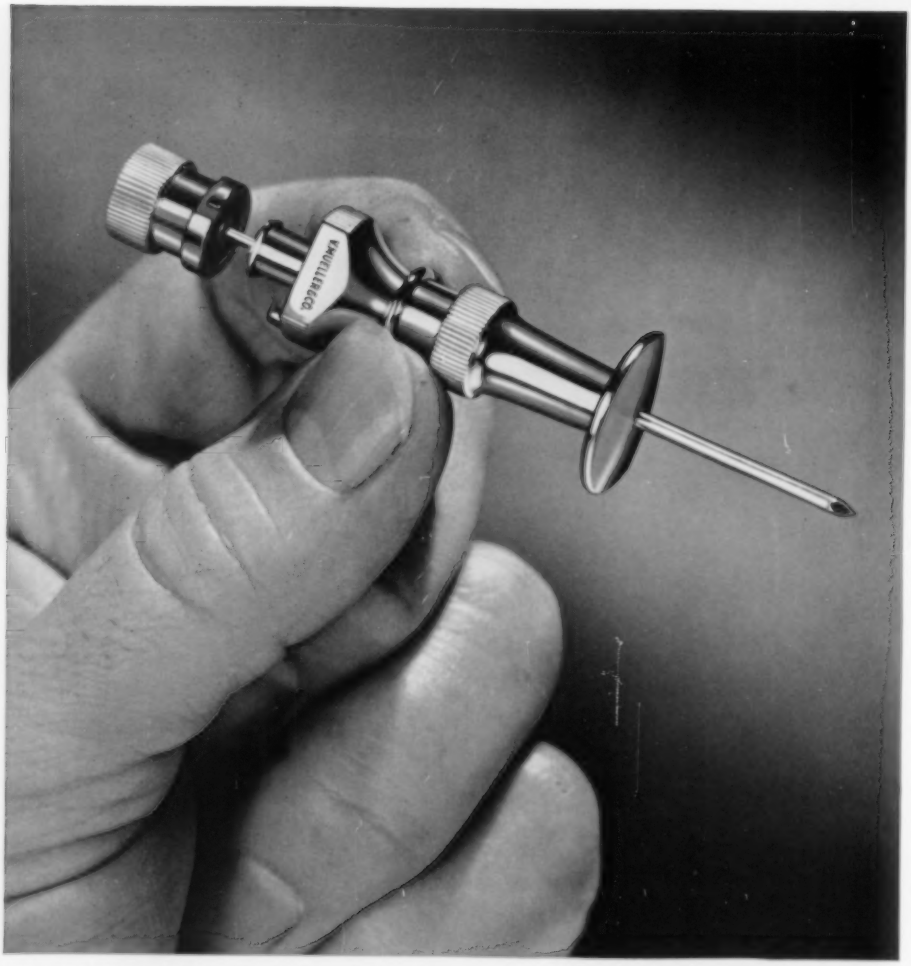
ZACK ROGERS ASSOCIATES INC.

5 BROADWAY • EAST PATERSON, NEW JERSEY • SW 7-8800

EXCLUSIVE WORLD-WIDE DISTRIBUTORS OF

ORTHO-TRAC

HOSPITAL ORTHOPEDIC AND FRACTURE EQUIPMENT




*to make the most of your talents and techniques . . .*

## University of Illinois Sternal Needle

V. Mueller research simplifies a dependable technique. Efficient for bone marrow aspirations from sternum, iliac crest, vertebra, tibia, femur, internal malleoli; also for marrow infusions. Depth of 15G, 1-inch cannula is adjustable; stylet locks in place. Stainless steel. Order as No. SU-21000, each $14.50.

# VMUELLER & CO.

*Fine Surgical Instruments and Hospital Equipment Since 1895*

330 S. Honore Street, Chicago 12, Illinois
Dallas • Houston • Los Angeles • Miami, Fla. • Rochester, Minn.



In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

## Parents can afford
# CHESBROUGH
## Orthopedic Pre-Walkers

**No. 1400 OPEN TOE**

Straight-line symmetrical last, firm heel, no back seam. Adaptable to Denis Browne Splints.

**No. 1300 CLOSED TOE**

Lace-to-toe design permits snug, gentle fit. Perfectly smooth inside.

**No. 1700 CLUBFOOT, OPEN TOE**

Special outflare last, sturdy instep strap to stabilize heel.

Louis C. Weld, President of G. W. Chesbrough Co. . . . "My own personal experience led to the development of the new Chesbrough Shoe."

Here are Orthopedic infants' shoes that meet rigid requirements of corrective footwear yet fit the family budget.

High-quality workmanship and fine leathers with orthopedically correct lasts are combined in Chesbrough Shoes to sell at a moderate price.

Any parent whose child requires orthopedic correction knows the expense is great, as frequent purchase of new shoes is required.

This problem was brought home to Chesbrough's president, Louis C. Weld, three years ago, when a child in his own family needed such a shoe. Recognizing the need for orthopedic shoes at an economical price, Chesbrough Company put their 60 years of shoemaking experience to work and Chesbrough Corrective Pre-Walker Shoes were born.

**All shoes** in unlined white elk, sizes 000 to 4, narrow and wide. Available in full pairs, split pairs or single shoes (no extra charge for half pairs).

*MAIL COUPON FOR FREE DESK SAMPLES*

---

**G. W. CHESBROUGH CO.**

**807 Smith Street, Rochester 6, N. Y.**

NAME_____

ADDRESS_____

CITY_____ STATE_____

YOUR ORTHOPEDIC SHOE DEALER

_____

when your patient needs
a potent steroid... simplified control
of subacute or chronic disease...

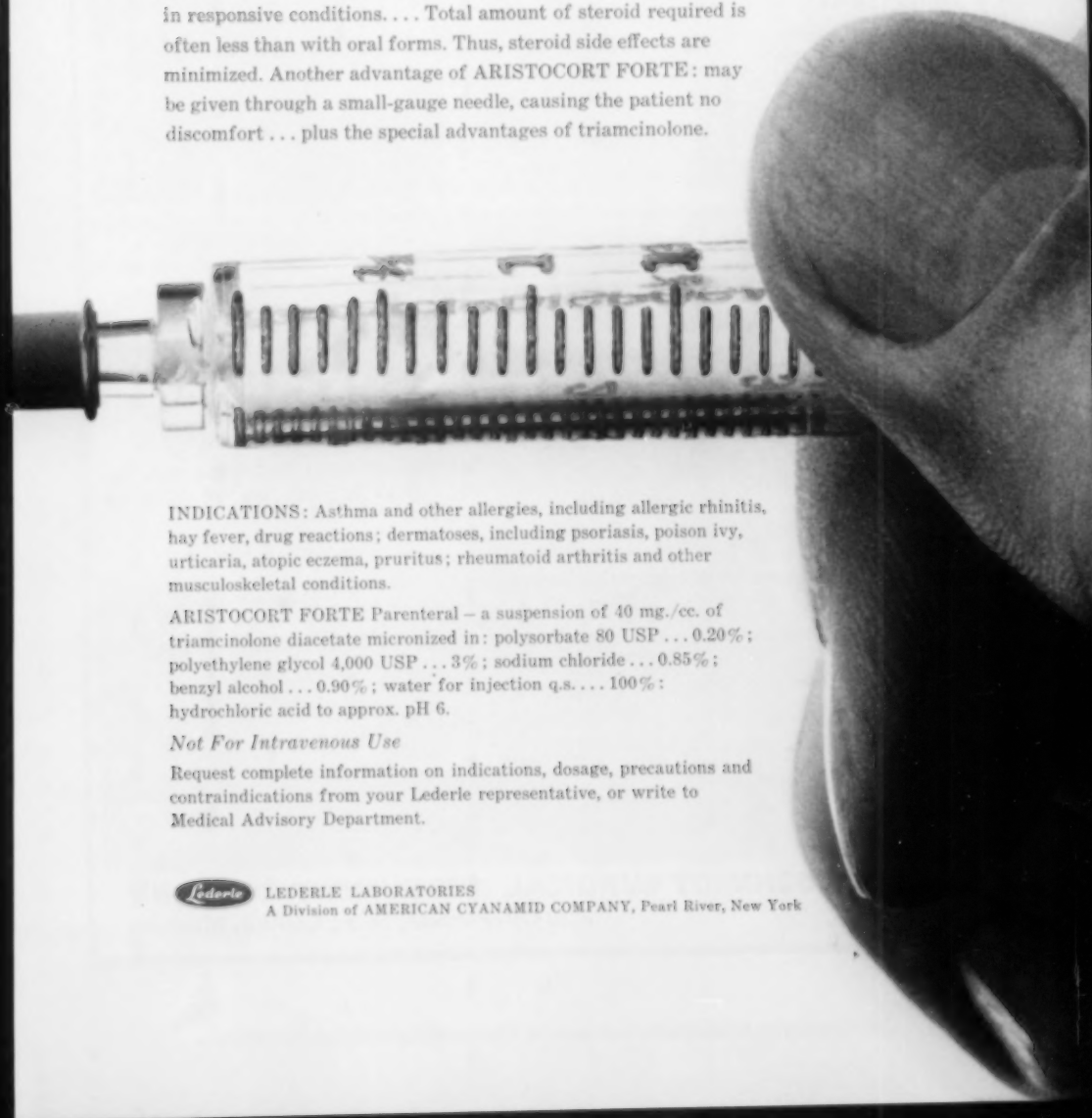
# New Aristocort® Forte

TRIAMCINOLONE

Diacetate Parenteral Suspension Lederle

## highly effective repository action with single, or infrequent, I.M. injections

Single I.M. doses of ARISTOCORT FORTE 4 to 7 times the usual daily oral dose can control symptoms 4 to 7 days, or even longer—sometimes up to 4 weeks in responsive conditions. . . . Total amount of steroid required is often less than with oral forms. Thus, steroid side effects are minimized. Another advantage of ARISTOCORT FORTE: may be given through a small-gauge needle, causing the patient no discomfort . . . plus the special advantages of triamcinolone.



INDICATIONS: Asthma and other allergies, including allergic rhinitis, hay fever, drug reactions; dermatoses, including psoriasis, poison ivy, urticaria, atopic eczema, pruritus; rheumatoid arthritis and other musculoskeletal conditions.

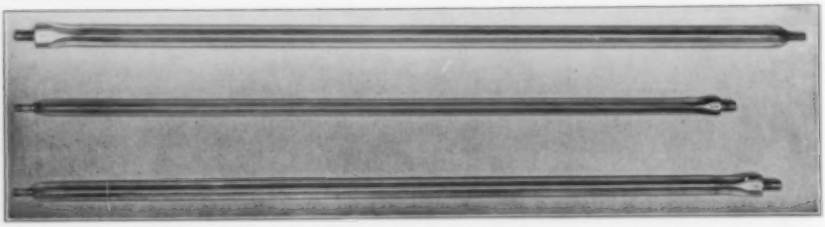
ARISTOCORT FORTE Parenteral – a suspension of 40 mg./cc. of triamcinolone diacetate micronized in: polysorbate 80 USP . . . 0.20%; polyethylene glycol 4,000 USP . . . 3%; sodium chloride . . . 0.85%; benzyl alcohol . . . 0.90%; water for injection q.s. . . . 100%: hydrochloric acid to approx. pH 6.

*Not For Intravenous Use*

Request complete information on indications, dosage, precautions and contraindications from your Lederle representative, or write to Medical Advisory Department.

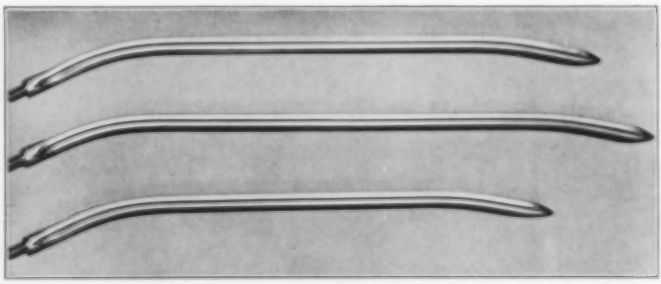
Lederle LEDERLE LABORATORIES
A Division of AMERICAN CYANAMID COMPANY, Pearl River, New York

# *LOTTES* NAILS and INSTRUMENTS

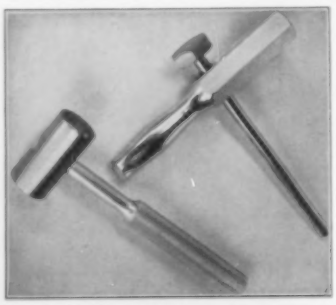


***LOTTES* FEMORAL NAILS** are manufactured with diameters of 3/8, 7/16, and 1/2 inches —with lengths in 1/2 inch variations from 14 to 20 inches.

***LOTTES* TIBIAL NAILS** are made in 7/16 and 3/8 inch diameters—in lengths from 9 to 15 1/2 inches, in variation of 1/2 inch.



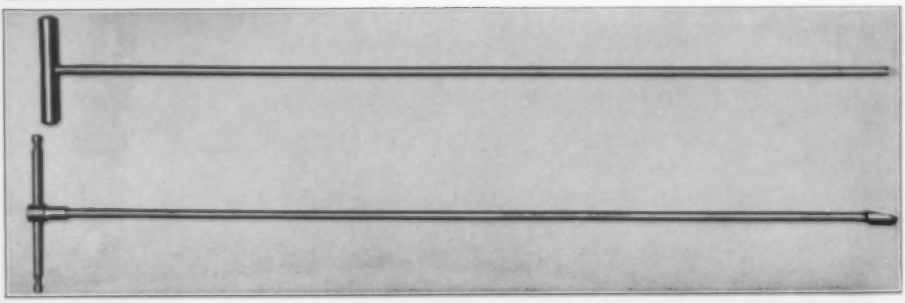
***LOTTES* NAILS AND INSTRUMENTS ARE MADE OF 18-8 SMo STAINLESS STEEL**



***LOTTES* DRIVER-EXTRACTOR COMBINATION and *LOTTES* MALLET**

***LOTTES* GUIDE WIRE AND *LOTTES* REAMER**

The reamer comes in 3 diameters: 3/8, 7/16, and 1/2 inch—all are 23 inches in length.



**CHAS. A. SCHMIDT SURGICAL INSTRUMENT COMPANY**

**3689 Olive Street, Saint Louis 8, Missouri**




In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

**OEC**
*Surgical*
**TOURNIQUET FAMILY**

**CONN-UNIVERSAL PNEUMATIC—NO. 750**
**Universal size** (fits practically all extremities). Rugged and time-proven. Vulcanized rubber cuff, with airplane buckle and new durable inflation system.

**CONN-KIDDE DELUXE AUTOMATIC—NO. 751**
Features universal size vulcanized rubber cuff with airplane buckle. Rugged, time-proven. Amazing new Kidde **visible gas reservoir** regulator.

**NEW KIDDE AUTOMATIC—NO. 752**
New Neoprene cuff with efficient Velcro® closure. Three sizes: 34", 24" (std), 12" x 2" (pediatric cuff) with amazing new automatic **visible gas reservoir** regulator.

**OEC-KIDDE—NO. 753**
The **economy** tourniquet. Durable new Conn inflation system and new Kidde Neoprene cuffs with efficient Velcro® closures. Popular in children's surgical work or where one size cuff is indicated. Three sizes: 34", 24" (std), 12" x 2" (pediatric cuff).

**order now**
from your surgical supply dealer

OEC®
Your Sign of Quality

**Orthopedic Equipment Co.**
Bourbon, Indiana
EUROPEAN ASSOCIATES: ZIMMER ORTHOPAEDIC LTD., Bridgend, Glam, Great Britain
ORTOPEDIA G.m.b.H. KIEL, Kiel, Germany

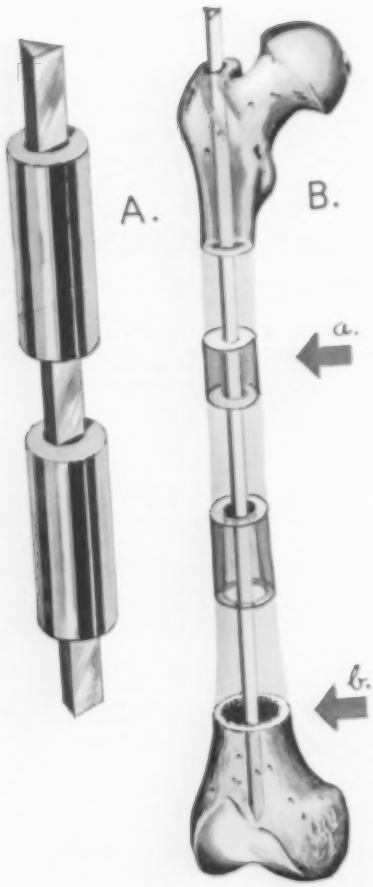
# Why . . . . .

The RUSH® MEDULLARY PIN

PAT. NO. 2,579,968



## Where is the Tight Rod Tight?




(A) A rod can be tightly impacted in a hollow pipe to control rotation because a pipe is of even contour and diameter throughout its entire length.

The medullary cavity of a bone, however, varies both in contour and diameter at various levels. A rod tightly impacted at one level will be loose at another.

(B) **Example femur.** A fracture of the upper half of the femur can be securely transfixed by any type of medullary rod because in this region, the bone is of fairly even diameter.

The medullary cavity is narrowest at the isthmus (a). The lower half of the medullary cavity is large and trumpet-shaped (b).

Any rod, which will pass through the isthmus (a), regardless of its shape in cross section, will be loose in the bone at (b)

Such a rod driven straight into the distal fragment must depend solely upon the doubtful firmness of the cancellous bone of the condyles for stability and the prevention of rotation of the lower fragment.

This is reliable only in young, active individuals. Cancellous bone has little substance in debilitated and inactive adults, and is almost absent in the elderly.

It thus becomes apparent that for stability of fixation of the lower fragment, the surgeon must depend not upon the irregularity of cross section of a straight rod, but upon the more dependable dynamic factors which can be utilized.

# Femur Shaft Technics

For **precise** fixation the technic must vary at different levels because of the trumpet interior of the femur.

(A) Pinning not indicated except in young individuals.

(B) Note modification of head of pin for stable fixation of upper fragment to prevent rotation and angulation.

(C) Single curved pin gives stable fixation by 3-point pressure.

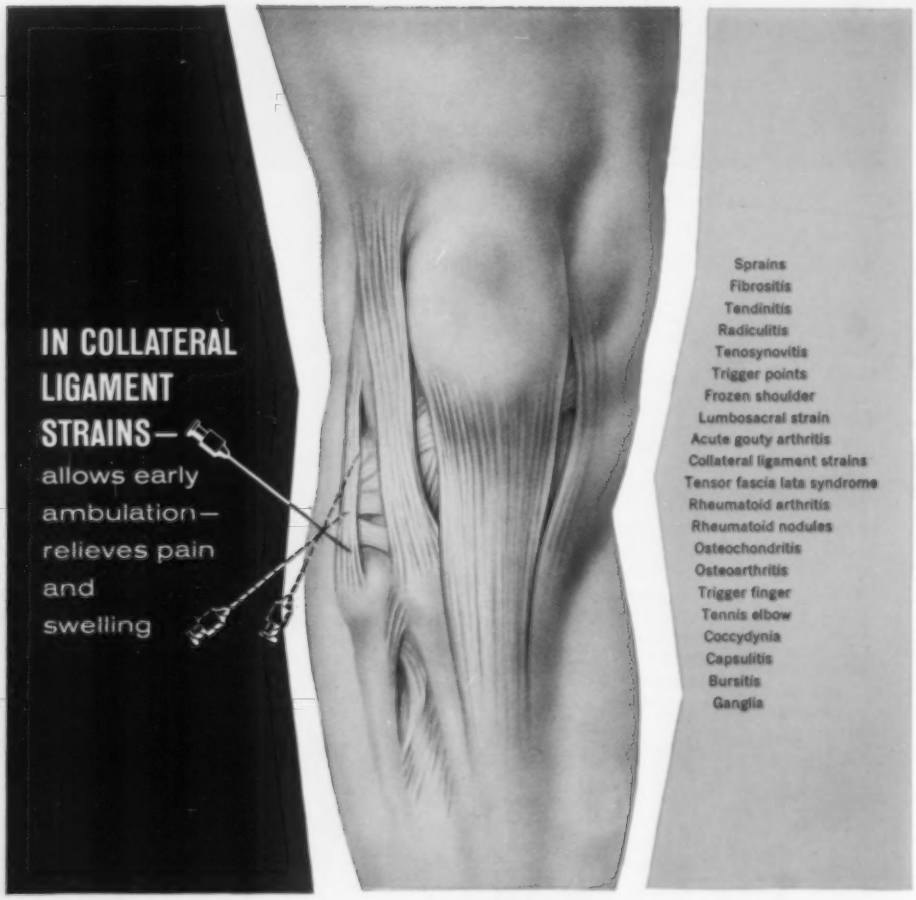
(D) Lower fragment is the problem. Addition of pin from internal condyle enhances stability.

(E) Bag of bones fracture fixed by double pins. Can usually be done as closed procedure. Spread of pins maintains length. Fascial envelope compresses fragments.

(F) Supra condylar and T fractures usually pinned as closed procedure.

THE BERIVON Company
Meridian, Miss.

EXCLUSIVE MANUFACTURERS OF **RUSH** MEDULLARY PINS AND INSTRUMENTS
Publishers of **"ATLAS OF RUSH PIN TECHNICS"** by LESLIE V. RUSH, M. D.




SUSPENSION

# HYDELTRA-T.B.A.®

PREDNISOLONE TERTIARY-BUTYLACETATE

## CONSISTENTLY EFFECTIVE—PROLONGED RELIEF

**Dosage:** the usual intra-articular, intrabursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

**Supplied:** Suspension HYDELTRA-T.B.A.—20 mg./cc. of prednisolone tertiary-butylacetate in 5-cc. vials.

Additional information is available to physicians on request. HYDELTRA-T.B.A. is a trademark of Merck & Co., INC.

MSD MERCK SHARP & DOHME
Division of Merck & Co., Inc., West Point, Pa.

VOLUME 43-A, NO. 6 SEPTEMBER 1961

The Journal of
Bone and Joint Surgery

*American Volume*

# Arthrodesis of the Knee by Double-Plating*

BY DONALD B. LUCAS, M.D., AND WILLIAM R. MURRAY, M.D.,
SAN FRANCISCO, CALIFORNIA

*From the Department of Orthopaedic Surgery, University of California School of Medicine, San Francisco*

When arthrodesis of the knee joint is indicated, the surgeon has a plethora of techniques at his disposal to obtain fusion (Fig. 1). Arthrodesis of this joint is usually not difficult to secure, using one of the presently accepted methods [2,3,5,6,7,9,10,11,12,13,16,19], and discussion of another method may seem redundant at this time. Occasionally, however, a situation arises when the usual surgical methods have failed or are not applicable to the problem at hand. We have found the two-plate method of fixation most useful in selected cases and believe that the success of this method offers adequate reason for presentation of our experiences.

The two-plate method is not new. In 1913 Osgood reported on the use of two aluminum or vanadium steel plates to immobilize the knee in fourteen patients. We were unaware of his use of this technique until recently, and interest in this method was an outgrowth of our success experienced in the treatment of fresh and ununited fractures of the long bones, using the two-plate method [21]. In long-bone fractures adequate immobilization is probably the single most important mechanical factor favoring union. Adequate immobilization is of equal importance in securing arthrodesis of the knee, since a knee joint denuded of articular cartilage does not differ greatly from a fresh or surgically treated ununited long-bone fracture. This method of fracture treatment has been employed by others [1,4,8,14,15,17,20,21,23]. It should be noted, however, that most authors reported on the use of two slotted plates applied in one or two planes, or two non-slotted plates applied in the same plane. When we used two plates in the operative treatment of fractures, we employed non-slotted plates applied in two planes. The rigid internal fixation and the success obtained with this method led to the adaptation of the two-plate method of fracture treatment to surgical arthrodesis of the knee.

During the past six years arthrodesis by this technique was performed on eighteen knees. The variety of conditions treated is shown in Table I. The uniform clinical success of the method attests to its mechanical soundness. The two stainless-steel plates, applied at 90 degrees to each other, produce two-plane fixation which effectively resists bending and rotational forces. The use of the plates

* Read at the Annual Meeting of the Western Orthopedic Association, Coronado, California, October 27, 1960.

TABLE I

DISEASE OF PATIENT AT ARTHRODESIS

| Disease | No. of Cases | Successful Fusion by Roentgenogram | No. of Operations Performed |
|---|---|---|---|
| Charcot knee | 4 | 4 | 4 |
| Septic arthritis | 3 | 3 | 3 |
| Tuberculosis | 2 | 2 | 3* |
| Post-traumatic arthritis | 3 | 3 | 3 |
| Degenerative arthritis | 1 | 1 | 1 |
| Rheumatoid arthritis | 4 | 4 | 4 |
| Giant-cell tumor | 1 | 1 | 1 |
| Totals | 18 | 18 | 19 |

* One failed on initial attempt (Case 8).

also permits preservation of maximum length of the extremity and exact positioning of the joint at the time of surgery.

METHOD

A pneumatic tourniquet is applied to the upper part of the thigh to control hemorrhage, and an extension of the median parapatellar approach is used for

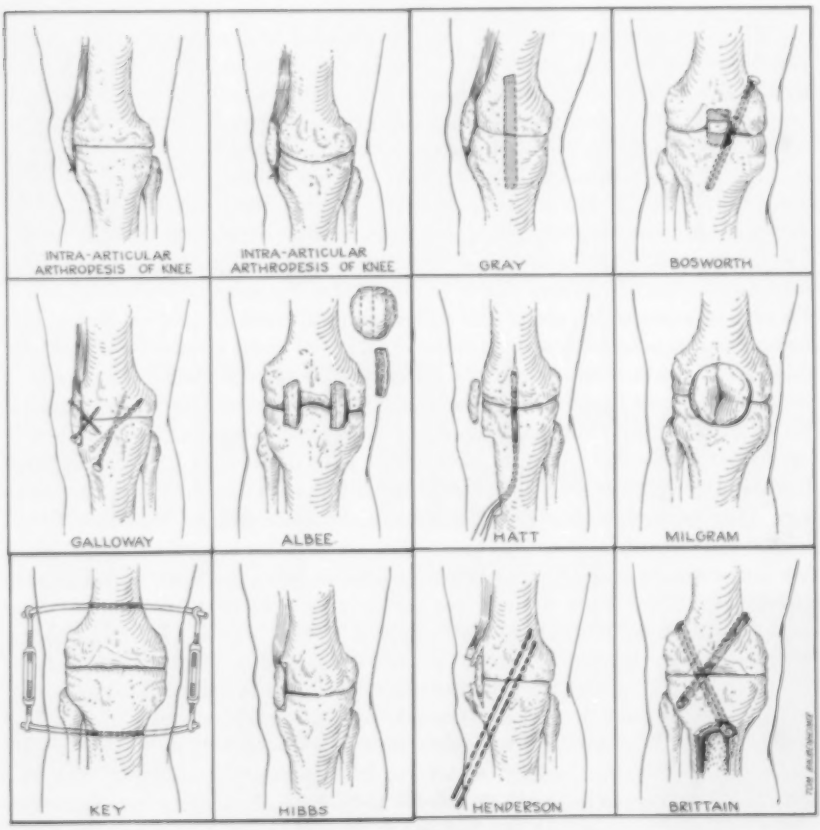



FIG. 1

Principal methods of arthrodesis of the knee. The drawings are adapted from each author's original publication.

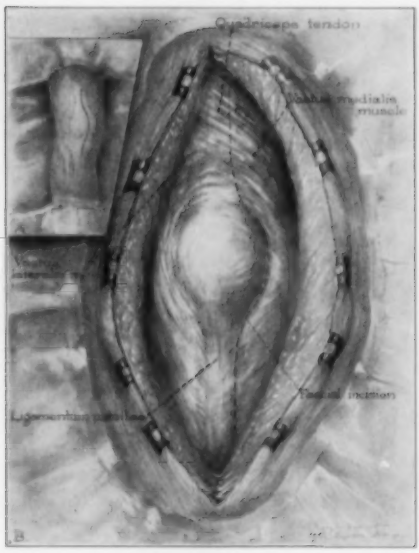



FIG. 2-A

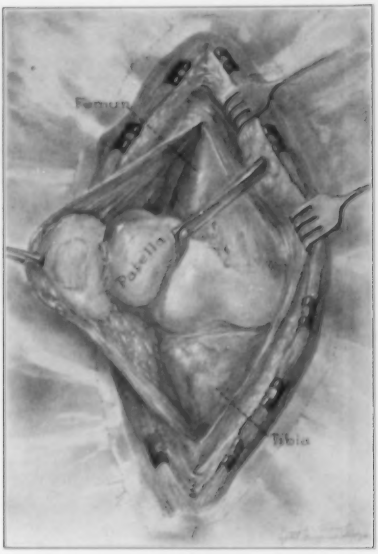



FIG. 2-B

Fig. 2-A: Technique of the two-plate method. The inset (*A*) shows the line of skin incision; *B* shows the skin and subcutaneous tissue reflected to visualize the underlying structures.

Fig. 2-B: The tibia and femur are exposed subperiosteally after incision of the quadriceps tendon and joint capsule. The patella is excised.

Fig. 2-C: After débridement of the joint, the femur and tibia are immobilized with two stainless-steel plates. Patellar grafts are packed around joint margins.

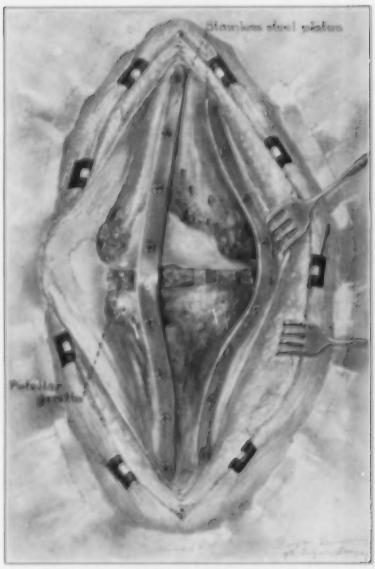



FIG. 2-C

exposure. The skin incision extends from about five inches above to approximately five inches below the joint (Fig. 2-A). The interval between the quadriceps tendon and the vastus medialis is exploited above the joint to permit subperiosteal exposure of the femur. Continuous flaps of skin, subcutaneous tissue, muscle, periosteum, and joint capsule thus formed are retracted, exposing the femur, tibia, and knee joint, as well as the undersurface of the patella (Fig. 2-B). The patella is excised and its cancellous portion utilized later as grafts to pack around the joint margin. Next, the joint capsule is freed sufficiently to allow excision of the menisci, cruciate ligaments, any joint debris, and the remaining articular cartilage. The femur and tibia are then brought together at the chosen angle (usually 165 degrees) [18] and held by an assistant while two plates are being shaped to fit the contour of the bones (Fig. 2-C). Commercially available, non-slotted, stainless-steel bone plates, eight inches long, approximately one-half inch wide, and 3/32 of an inch thick, are satisfactory. To obtain accurate fitting of the plates, shaping in two planes is required. This may be done easily with the presently available commercial benders. We

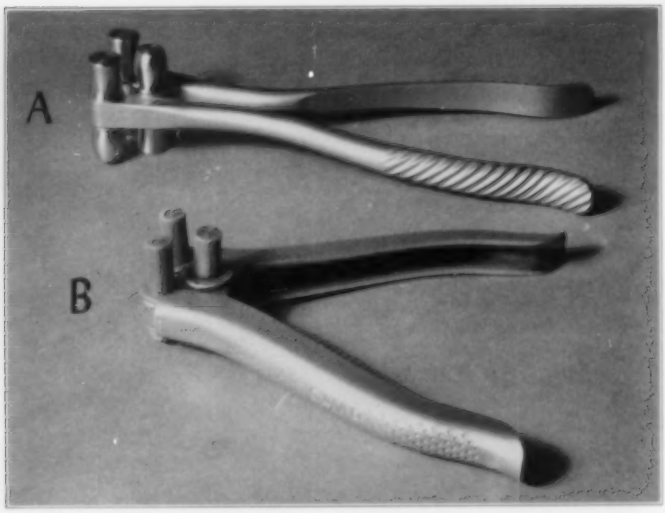



FIG. 3

*A* is a commercially available plate bender; *B*, an adapted corset iron bender.

have found a modified corset iron bender to be quite satisfactory (Fig. 3). Minor contouring of the bones often facilitates fitting of the plates. The plates are applied in planes at 90 degrees to each other, one on the anterior and one on the medial surface, whenever possible (Fig. 2-C). The lateral surface is used if there has been destruction of bone on the medial surface. Bone-holding forceps may be used to advantage to hold the plates while they are being secured with machine thread screws which pierce both cortices of the bones. In some instances when the bone is soft and the screws do not seat well, washers and nuts are added to give additional fixation. Small fragments of bone from the patella are packed in the joint margins to fill any defects. Routine closure is effected in layers after deflation of the tourniquet and control of hemorrhage. In the majority of cases only a soft, supportive dressing has been used. We apply a plaster cylinder case from above the ankle to the upper part of the thigh if at the time of surgery the bone has been found to be unusually soft.

After removal of the sutures, the patient is allowed to walk on crutches without weight-bearing. Partial weight-bearing is usually permitted at approximately twelve weeks after operation, and full weight-bearing is started when there is roentgenographic evidence of union. Although clinically adequate union may be present before there is roentgenographic evidence of fusion, we have not advised unguarded weight-bearing until the roentgenogram confirms the presence of bone fusion.

## CASE REPORTS

A summary of all eighteen patients treated to date is shown in Table II; five have been selected for detailed presentation.

CASE 1. A white woman, born on July 7, 1911, was first seen in 1952 at the University of California Medical Center requesting amputation because of persistent pain in the right knee. Pyogenic arthritis of the right knee had developed after whooping cough in infancy. Attempted fusion, when she was sixteen years old, had failed. A further attempt in 1952 by the Key compression technique also failed, largely because of the patient's obese thigh, which made effective immobilization impossible (Fig. 4-A). In March 1954, arthrodesis by the two-plate method was per-

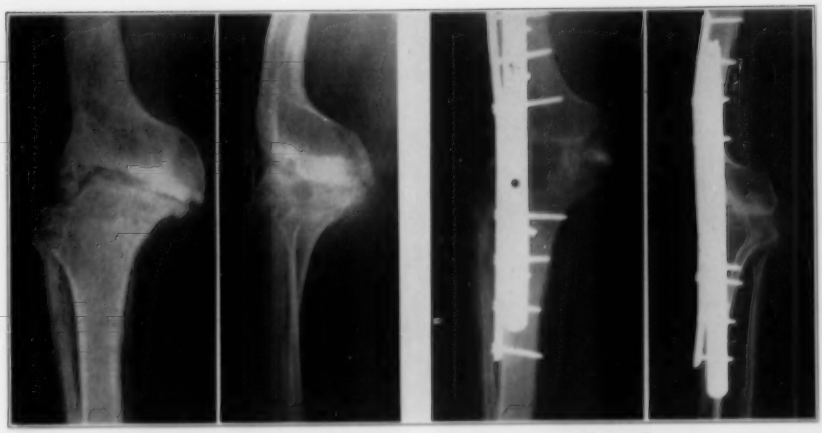


FIG. 4-A FIG. 4-B

Fig. 4-A: Case 1. Roentgenographic appearance of the knee two years after attempted fusion by the Key compression technique.
Fig. 4-B: Roentgenograms made ten months after arthrodesis by the two-plate method.

FIG. 5-A FIG. 5-B

Fig. 5-A: Case 3. Roentgenograms made before surgery showing recurrent giant-cell tumor of the lateral tibial condyle.
Fig. 5-B: Roentgenograms made two and one-half years after resection of the tumor and arthrodesis of the knee, utilizing the femoral graft and double-plating.

formed. Partial weight-bearing was permitted four months after operation and full weight-bearing at six months, when roentgenograms showed evidence of bone union. (The roentgenographic appearance at ten months is shown in Figure 4-B.) In September 1959, five and one-half years after arthrodesis, a moderately painful bursa developed over the anterior plate, and in January 1960, both plates were removed. In this patient, two previous procedures had failed, and the two-plate method was selected because rigid internal fixation seemed to be the only way in which adequate immobilization could be secured in such an obese patient.

CASE 3. A white woman, born on July 18, 1920, had a giant-cell tumor at the proximal end of the left tibia when first seen at the University of California Medical Center in September 1956. Curettage and bone-grafting had been performed elsewhere in December 1955, after which there was rapid recurrence and break-through of the tumor into the joint (Fig. 5-A). In September 1956, segmental resection of the tumor and modified dual-plating were carried out. (Roentgenograms

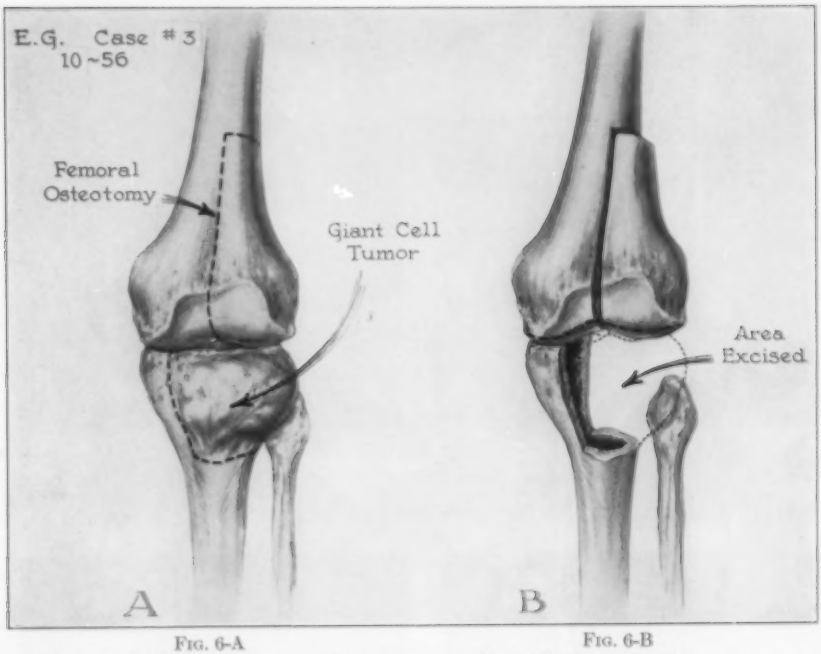



FIG. 6-A FIG. 6-B

Fig. 6-A: Case 3. Giant-cell tumor of the tibia and outline of the femoral graft.
Fig. 6-B: Excision of the tumor and osteotomy of the femur.

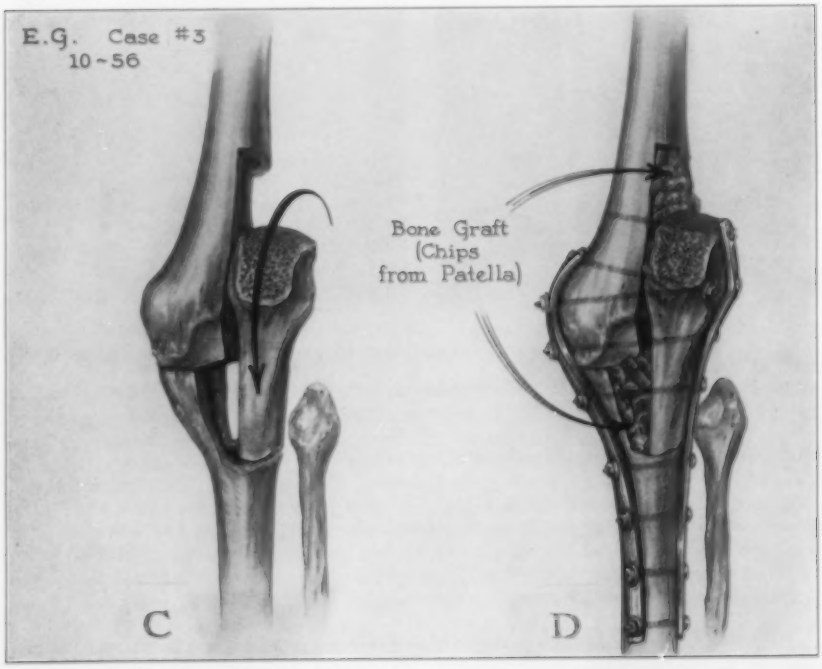



FIG. 6-C FIG. 6-D

Fig. 6-C: The osteotomized portion of the femur turned down as a graft across the joint line.
Fig. 6-D: The final position after application of the plates and use of the patellar fragments as an additional bone graft.

made two and one-half years later are shown in Figure 5-B.) A portion of the femur was turned down as a graft. Figures 6-A through 6-E show the technical details of the operation. In this patient two-plate application of the plates was not feasible. Unfortunately, the femur was fractured on the operating table, and a hip spica cast was necessary for three months after operation. Partial weight-bearing was instituted at six months and crutches were discarded twelve months after surgery. There was no evidence of recurrence of the tumor during the four and one-half years of follow-up. The two-plate method was selected in this patient to retain length and alignment of the extremity after segmental resection of the proximal end of the tibia. At the time of writing there is approximately three-quarters of an inch of shortening.

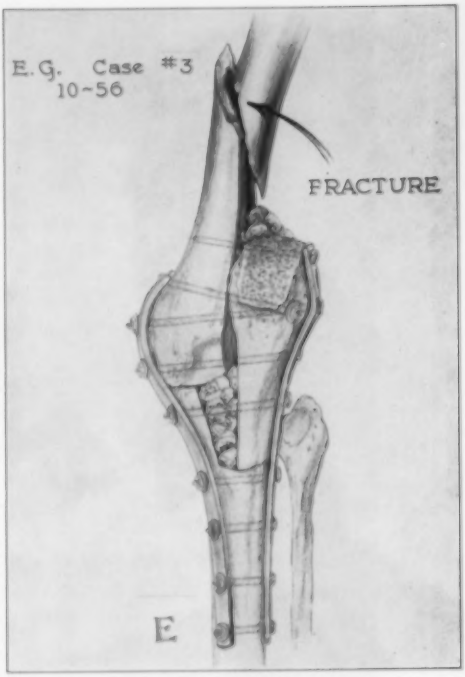



FIG. 6-E

The fracture in the weakened portion of the femur.

CASE 4. A white woman, born on January 5, 1915, entered the University of California Medical Center in 1957 with a diagnosis of tabes dorsalis and neurogenic arthropathy of the right knee. One year prior to admission patellectomy for chondromalacia had been done. On admission, in 1957, the patient was complaining of severe pain and instability in the right knee (Fig. 7-A). She was unable to walk without support. The diagnosis was confirmed, and arthrodesis by the two-plate method was carried out. Against advice, the patient began partial weight-bearing at the end of one month and discarded the crutches at the end of three months. Despite failure to follow the prescribed regimen, no complications ensued, and roentgenographic evidence of solid bone union was present five months after operation. Roentgenograms made one year after surgery are shown in Figure 7-B.

CASE 6. A white woman, born on April 9, 1888, had tabes dorsalis and neurogenic arthopathy of the right knee and right shoulder. In 1952, because of persistent pain and stiffness of the right knee, fusion by the use of multiple intramedullary rods had been attempted at another hospital. This procedure failed and the rods broke (Fig. 8-A). The patient was sixty-eight years old when she was first seen at the University of California Medical Center, where the original diagnosis was confirmed. Treatment for syphilis was instituted at that time. On November 11, 1957, the rods were removed and arthrodesis was performed, utilizing the two-plate method. Partial weight-bearing was permitted with crutches two months after operation. Four months after surgery (Fig. 8-B) the patient had an excellent gait when using a cane. Roentgenograms showed union to be complete at six months; Figure 8-C shows the appearance of the knee at eighteen months. The two-plate method was selected for arthrodesis of this knee in view of our previous success in Charcot knees and because of the failure of the initial procedure.

CASE 8. A white man, born on June 16, 1905, had tuberculous arthritis of the left knee (Fig. 9-A). A clinical diagnosis of degenerative joint disease was made and in February 1958, fusion, using two plates, was attempted. The patella was not excised. Culture and guinea-pig inoculation of specimens obtained at surgery established the diagnosis of tuberculous arthritis. Postoperative anti-tuberculosis therapy consisting of five grams of para-aminosalicylic acid, three times a day, and streptomycin, one gram twice a week, was continued for fifteen months. Against advice, the patient began partial weight-bearing at the end of the first postoperative month. Two months later motion was noted, and a posterior plaster splint was applied. Five months after operation a leather lacer was fitted to the extremity, and partial weight-bearing was permitted. Increasing pain gradually developed. Twelve months after operation gross motion was evident (Fig. 9-B). Fourteen months after the original arthrodesis a second procedure was performed, and granulation and scar

FIG. 7-A

Case 4. Preoperative roentgenograms showing neuropathic joint due to tabes dorsalis.

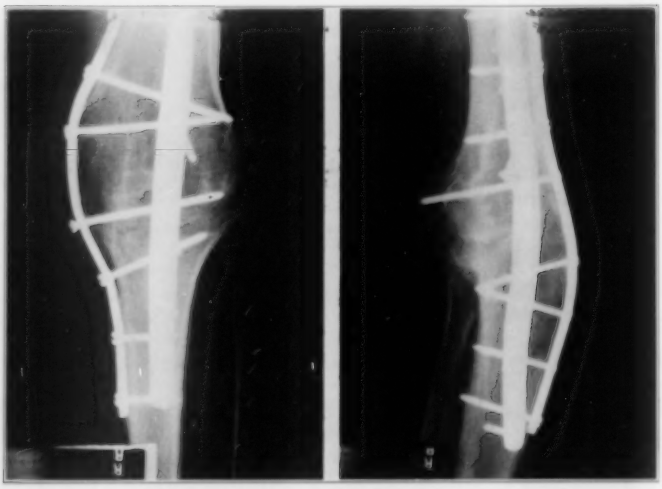


FIG. 7-B

Roentgenograms made one year after arthrodesis.

tissue was excised from the joint. The patella was excised and used as a graft. The original plates showed no gross evidence of corrosion; they were reshaped and reapplied, new screw holes being utilized. Cultures for acid-fast bacilli were negative after the second procedure, and the patient was permitted to discontinue the para-aminosalicylic acid and streptomycin. After operation the extremity was placed in a cylinder cast which was removed thirteen weeks later, when partial weight-bearing was allowed. Twenty-one weeks after surgery fusion was solid both clinically and roentgenographically, and the patient resumed full activity. The appearance of the joint at one year is shown in Figure 9-C.

In our judgment failure of fusion in the first attempt resulted from too early weight-bearing with loss of rigid fixation in this uncooperative patient with osteoporotic bone. We now use a plaster cylinder in such cases.

## DISCUSSION

It was our intention at the outset to reserve double-plating for unusual cases. Because of its simplicity and ease of execution, however, it has now become our routine technique for arthrodesis of the knee. Aside from the fact that it is a highly

FIG. 8-A

Case 6. Roentgenograms showing failure of fusion and broken rods in a Charcot (right) knee.

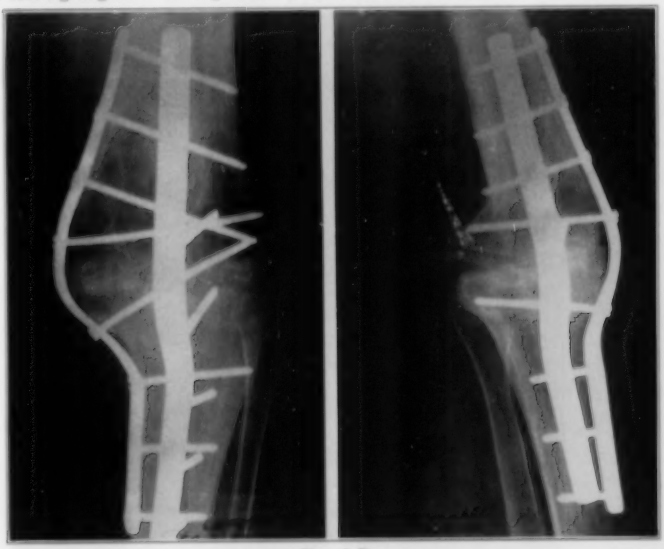


FIG. 8-B

Roentgenograms made four months after arthrodesis by the two-plate method.

successful means of obtaining knee fusion, the method has several other strong points in its favor.

*Advantages of the Method*

1. Maximum length of the extremity is maintained since only the cartilage and a minimum amount of subchondral bone are removed at surgery. No attempt is made to obtain parallel surfaces by cutting back the cancellous bone. Also, large defects may be bridged (Case 3), and the maximum length of the extremity preserved.

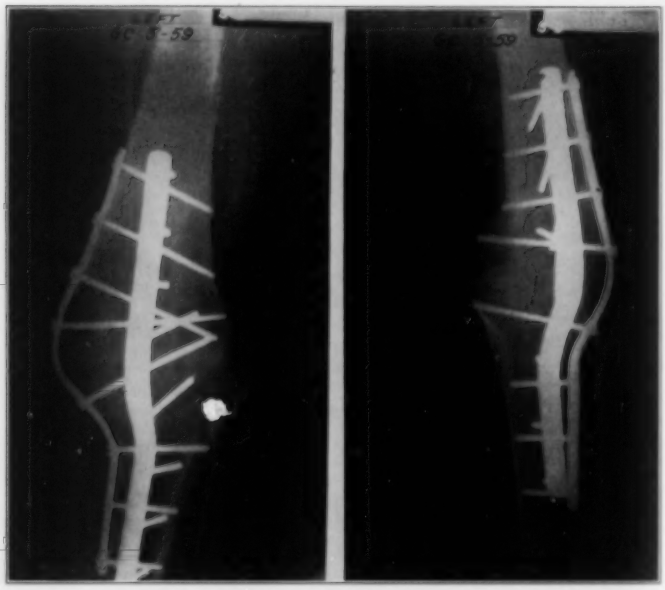


FIG. 8-C

Roentgenograms made eighteen months after arthrodesis.

FIG. 9-A

Case 8. Roentgenograms of the left knee showing tuberculous arthritis.

2. The knee may be fixed in any position desired at the time of surgery, and the position maintained with certainty during convalescence. At operation, the position of arthrodesis is selected and the plates are contoured and applied while maintaining the position. Ordinarily, we prefer the position of 165 degrees

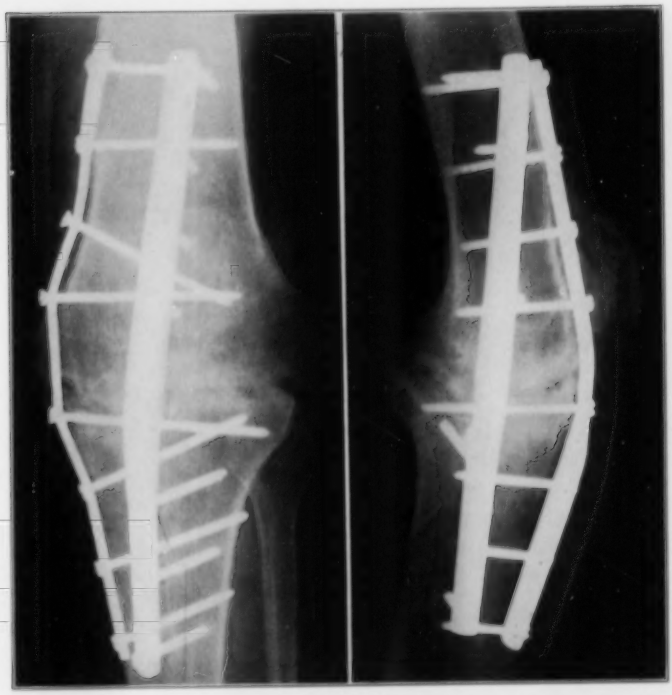


FIG. 9-B

Roentgenograms made twelve months after attempted arthrodesis, showing failure of fusion.

FIG. 9-C

Roentgenographic appearance of the left knee one year after second operation.

TABLE II

END RESULTS IN EIGHTEEN PATIENTS

| Case No. | Age at Operation (*Years*) | Diagnosis | Duration of Symptoms (*Years*) | Prior Surgery | Date of Present Operation | External Fixation | Duration of Partial Weight-Bearing (*Months*) | Time until Full Weight-Bearing (*Months*) | Time of Roentgenographic Evidence of Fusion (*Months*) | Complications |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 43 | Old septic arthritis | 41 | Intra-articular arthrodesis, 1917, failed; Key compression arthrodesis, 1952, failed | March 1954 | None | 4 | 6 | 6 | None; bursa over anterior plates; both plates removed Jan. 1960 |
| 2 | 33 | Old septic arthritis | 20 | None | 1955 | None | 3 | 5 | 5 | None |
| 3 | 36 | Giant-cell tumor | 2 | Curettage and bone-grafting, 1955 | Sept. 1956 | 1½ hip spica | 6 | 12 | 12 | Fracture of femur at time of surgery |
| 4 | 42 | Charcot knee | 2 | Patellectomy, 1956 | 1957 | None | 1 | 3 | 5 | None |
| 5 | 60 | Charcot knee | 6 | None | 1957 | None | 1½ | 2½ | 5 | None |
| 6 | 70 | Charcot knee | 6 | Arthrodesis with multiple rods, 1952, failed | Nov. 1957 | None | 2 | 4 | 6 | None |
| 7 | 35 | Rheumatoid arthritis | 19 | Tibial osteotomy | 1957 | None | 3 | 6 | 6 | None |
| 8 | 53 | Tuberculosis | 18 | Two-plate method arthrodesis, Feb. 1958, failed | Apr. 1959 | Plaster cylinder, 3 mos. | 3 | 5 | 5 | First attempt with two-plate fusion failed |
| 9 | 60 | Tuberculosis | 8 | None | 1958 | None | 7 | 7 | 7 | None |
| 10 | 38 | Post-traumatic arthritis | 2 | Open reduction tibial-plateau fracture | 1959 | Plaster cylinder, 4½ mos. | 3 | 6 | 6 | None |
| 11 | 68 | Charcot knee | 11 | None | 1959 | Plaster cylinder, 5 mos. | 5 | 6 | 6 | None |
| 12 | 49 | Post-traumatic arthritis | 37 | None | 1959 | Plaster cylinder, 2 mos. | 5 | 5 | 5 | None |
| 13 | 61 | Rheumatoid arthritis | 20 | None | 1960 | None | 2 | 6 | 6 | None |
| 14 | 22 | Rheumatoid arthritis | 6 | None | 1960 | Plaster cylinder, 1 mo. | 3 | 5 | 5 | None |
| 15 | 52 | Post-traumatic arthritis | 5 | None | 1960 | None | 6 | 6 | 6 | None |
| 16 | 43 | Septic arthritis, right knee | 3½ | Open reduction, right tibia; ligament repair, right knee | 1960 | None | 2 | 4 | 6 | Intermittent drainage, 1 yr. |
| 17 | 58 | Rheumatoid arthritis | 17 | None | 1960 | Plaster cylinder, 3 mos. | 2 | 5 | 5 | None |
| 18 | 48 | Degenerative arthritis | 2½ | Patellectomy | 1960 | Plaster cylinder, 3 mos. | 3 | 5 | 6 | None |

since studies have shown that this position requires the least expenditure of energy during walking [18].

3. The extremity does not require external support during convalescence unless the bone is extremely osteoporotic or the patient is uncooperative. In those instances, a light-weight plaster cylinder is advocated.

4. From an economic standpoint, the method is attractive because it permits early discharge of the patient from the hospital, obviates the necessity for long recumbency, and, in most instances, allows the patient to walk on crutches soon after surgery.

*Disadvantages of the Method*

1. In some instances the plates may require removal if painful adventitious bursae develop.

2. At first, the surgeon may experience difficulty in the bending and application of the plates, but as familiarity with the technique is gained, this procedure becomes easier.

SUMMARY

A technique for arthrodesis of the knee, using two eight-inch stainless-steel plates applied to the anterior and medial aspects of the femur and tibia at 90 degrees to each other, is presented. The procedure has been used successfully on four knees with neurogenic arthropathy secondary to tabes dorsalis, three knees with old septic arthritis, two knees with tuberculous arthritis, three knees with post-traumatic arthritis, as well as four knees with rheumatoid arthritis, one knee with a segmental resection of the proximal end of the tibia for giant-cell tumor, and one knee with degenerative arthritis. There was only one failure, and this knee went on to solid fusion after a second plating procedure. External support was seldom required, and walking with crutches shortly after operation was possible in most instances, with partial weight-bearing usually permitted by three months and full weight-bearing after six months. The method described makes it possible to preserve maximum length and even to bridge defects; it assures arthrodesis in the optimum position with minimum hospitalization. Of the eighteen cases reported, removal of the plates was subsequently performed in five instances.

REFERENCES

1. Adams, J.D., and Coonse, G.K.: Complete Rigid Internal Fixation by Double Plating Fractures of Long Bones. Proc. Inst. Med., Chicago, **18**: 98–99, 1948.
2. Albee, F.H.: Bone-Graft Surgery, pp. 276–296. Philadelphia, W.B. Saunders Co., 1915.
3. Bosworth, D.M.: Knee Fusion by the Use of a Three-Flanged Nail. J. Bone and Joint Surg., **28**: 550–554, July 1946.
4. Breck, L.W., and Basom, W.C.: The Dual Plate, No Cast, Internal Fixation of Shaft Fractures. Southern Med. J., **37**: 582–584, 1944.
5. Brittain, H.C.: Architectural Principles in Arthrodesis, pp. 46–52. Baltimore, The Williams and Wilkins Co., 1942.
6. Charnley, J.C.: Positive Pressure in Arthrodesis of the Knee Joint. J. Bone and Joint Surg., **30-B**: 478–486, Aug. 1948.
7. Charnley, J.C., and Baker, S.L.: Compression Arthrodesis of the Knee. A Clinical and Histological Study. J. Bone and Joint Surg., **34-B**: 187–199, May 1952.
8. Eggers, G.W.N.: Internal Contact Splint. J. Bone and Joint Surg., **30-A**: 40–52, Jan. 1948.
9. Galloway, H.P.H.: The Patellar Bone-Graft in Excision of the Knee. Am. J. Orthop. Surg., **15**: 704–710, Oct. 1917.
10. Gray, H.T.: The Stabilization of the Flail Leg. British J. Surg., **15**: 390–400, 1927–28.
11. Hatt, R.N.: The Central Bone Graft in Joint Arthrodesis. J. Bone and Joint Surg., **22**: 393-402, Apr. 1940.
12. Henderson, M.S., and Fortin, H.J.: Tuberculosis of the Knee Joint in the Adult. J. Bone and Joint Surg., **9**: 700–713, Oct. 1927.
13. Hibbs, R.A.: An Operation for Stiffening the Knee-Joint. With Report of Cases from the Service of the New York Orthopaedic Hospital. Ann. Surg., **53**: 404–407, 1911.
14. Kaplan, I.W., and Craighead, C.C.: Two-Plane Fixation of Fractures of the Femoral Shaft with Eggers' Plates. Am. J. Surg., **89**: 862–866, 1955.

15. KEY, J.A.: Dual Plates for Internal Fixation in Non-union of Fractures. J. Bone and Joint Surg., **27**: 632–636, Oct. 1945.
16. KEY, J.A.: Positive Pressure in Arthrodesis for Tuberculosis of the Knee Joint. Southern Med. J., **25**: 909–915, 1932.
17. LINQUIST, C.A.: Double Plates in Rectangular Planes for Internal Fixation of Fractures of the Femur. Ann. Western Med. and Surg., **2**: 93–97, 1948.
18. MAZZETTI, R.F.: Effect of Immobilization of the Knee on Energy Expenditure During Walking. *In* Proceedings of the Western Orthopedic Association. J. Bone and Joint Surg., **42-A**: 533, Apr. 1960.
19. MILGRAM, J.E.: A Modification of the Rotation Arthrodesis of the Knee (Roeren). Surg., Gynec., and Obstet., **53**: 355–359, 1931.
20. MUMFORD, E.B.: Fracture of the Shaft of the Femur. J. Indiana State Med. Assn., **41**: 599–602, 1948.
21. MURRAY, W.R.: Unpublished data.
22. OSGOOD, R.B.: The End Results of Excision of the Knee for Tuberculosis with and without the Use of Bone Plates. Boston Med. and Surg. J., **169**: 123–125, 1913.
23. PETERSON, L.T., and REEDER, O.S.: Dual Slotted Plates in Fixation of Fractures of the Femoral Shaft. A Report of Eighteen Cases. J. Bone and Joint Surg., **32-A**: 532–541, July 1950.

# A Comparative Study of the Two Popular Methods of Measuring Scoliotic Deformity of the Spine

BY K. GEORGE, M.D.,* AND J. RIPPSTEIN, M.D.,** LOS ANGELES, CALIFORNIA

*From the J. C. Risser Research Foundation and the Scoliosis Clinic, Orthopaedic Hospital, Los Angeles*

To evaluate the results of treatment of the scoliotic deformity, the patient's improvement should be judged by both clinical and roentgenographic examination. Clinical examination should take note of such points as improvement in height, reduction of the rib angulation, correction of trunk list, and lack of compensation in compensatory curves. The roentgenographic examination should measure the spinal curvature, the deviation of the convexity of the curve from the central plumb line, and the vertebral rotation. This study concerns the measurement of the angulation of the scoliotic deformity and positional changes of the apex of the deforming curve.

There are two popular and widely used methods of measurement of the scoliotic angulation (Figs. 2-A, 2-B, 3-A, and 5-A). The first was introduced by Ferguson at the New York Orthopaedic Hospital in the early 1920's. It is as follows: On the roentgenogram the shadows of the lateral margins of the apical vertebra and the vertebrae at the ends of the curve are outlined, and the central points of these vertebrae are marked. The end vertebrae are identified as the vertebrae which are neutral as to angulation and, usually, as to rotation at the top and bottom of the curve. In a few cases where the compensating lumbar curve is inadequate, the rotational deformity of the deforming curve may extend lower than the angular deformity. In these cases, the vertebrae that are neutral as to angulation are selected as the end vertebrae and their centers marked. The supplementary angle formed by straight lines joining the central points of the apical and two end vertebrae is defined as the angle of curvature. The second method was introduced by Lippman [1] in 1935 and popularized by Cobb [1], also in New York. By this method, the scoliotic angulation is the angle formed by the intersection of lines drawn perpendicular to the superior surface of the top vertebra and the inferior surface of the bottom vertebra.

When these two methods are applied to a given case, the angles measured are quite different. This difference becomes most marked when the amount of correction is measured. Therefore, if the results of treatment are recorded as percentages of correction, the result in a given case will vary according to the method of measurement employed. For this reason it seemed important to compare these two methods of measurement in some detail.

## COMPARATIVE STUDIES

In this comparative study, twenty-five curves of various types were carefully measured by both methods. In Table I, the measurements before and after cor-

* Fellow in Scoliosis, Risser Research Foundation and Scoliosis Clinic of the Los Angeles Orthopaedic Hospital.

** Chief of the Clinic, Orthopaedic Hospital, University of Lausanne, Switzerland.

TABLE I

COMPARATIVE MEASUREMENTS OF THE LATERAL CURVATURES OF THE SPINE BY THE COBB METHOD AND THE FERGUSON METHOD

| Patient | Extent of Curve | Measurement before Correction | | Measurement after Correction | | Percentage of Correction | | Percentage Difference |
|---|---|---|---|---|---|---|---|---|
| | | Cobb Method | Ferguson Method | Cobb Method | Ferguson Method | Cobb Method | Ferguson Method | |
| L.L. | T4-T8-T12 | 48 | 43 | 30 | 33 | 37 | 23 | 14 |
| T.S. | T5-T8-T12 | 40 | 30 | 13 | 14 | 67 | 53 | 14 |
| D.R. | T5-T9-L1 | 50 | 43 | 22 | 27 | 56 | 37 | 19 |
| C.L. | T6-T9-T12 | 41 | 33 | 15 | 16 | 63 | 51 | 12 |
| P.McD. | T10-L1-L3 | 55 | 45 | 27 | 28 | 50 | 37 | 13 |
| P.B. | T8-T12-L3 | 37 | 28 | 8 | 13 | 78 | 53 | 25 |
| R.C. | T6-T9-L1 | 52 | 37 | 14 | 12 | 73 | 67 | 6 |
| A.K. | T5-T8-T11 | 28 | 21 | 5 | 7 | 82 | 66 | 16 |
| H.V.deV. | T9-L1-L5 | 67 | 50 | 46 | 41 | 31 | 18 | 13 |
| S.L. | T6-T11-L3 | 35 | 27 | 3 | 10 | 91 | 63 | 28 |
| K.G. | T5-T8-T11 | 65 | 40 | 22 | 22 | 66 | 45 | 21 |
| L.F. | T6-T10-L2 | 70 | 48 | 20 | 20 | 71 | 58 | 13 |
| D.F. | T7-T9-T12 | 90 | 66 | 54 | 49 | 40 | 25 | 15 |
| D.L. | T5-T9-L1 | 88 | 60 | 46 | 42 | 47 | 30 | 17 |
| V.G. | T4-T7-T10 | 49 | 37 | 24 | 22 | 51 | 40 | 11 |
| | T11-L1-L4 | 48 | 36 | 17 | 19 | 64 | 47 | 17 |
| T.D. | T10-L1-L3 | 39 | 52 | 11 | 13 | 71 | 59 | 12 |
| I.D. | T5-T8-T10 | 42 | 28 | 15 | 14 | 64 | 50 | 14 |
| C.A. | T6-T10-L2 | 63 | 47 | 27 | 24 | 57 | 48 | 9 |
| S.D. | T4-T8-T11 | 39 | 29 | 4 | 7 | 89 | 75 | 14 |
| | T12-L2-L5 | 39 | 27 | 11 | 15 | 71 | 44 | 27 |
| B.McD. | T5-T8-T10 | 97 | 73 | 72 | 67 | 25 | 8 | 17 |
| P.A. | T5-T9-T12 | 45 | 30 | 5 | 7 | 88 | 76 | 12 |
| B.C. | T9-T12-L3 | 60 | 36 | 30 | 27 | 50 | 25 | 25 |
| C.C. | T11-L2-L4 | 64 | 40 | 30 | 28 | 53 | 30 | 23 |
| A.D. | T5-T9-T12 | 45 | 29 | 5 | 7 | 88 | 75 | 13 |
| P.H. | T11-L1-L3 | 47 | 38 | 5 | 9 | 89 | 76 | 13 |
| | Averages: | | | | | 63 | 47 | 16 |

rection are recorded, as well as the percentage of correction and the percentage difference between the two methods. The angles recorded before correction are consistently higher with the Cobb method.

After correction the measurements taken with the two methods tend to approximate one another. In addition, in about half of the cases, the measurements after correction by the Cobb method are less than those obtained by the Ferguson method. As a result, the percentage of improvement as determined by the Cobb method is greater. This difference is shown in the last column of Table I. Since the results of treatment are often reported as percentage of improvement from the original curve, these differences in the results by the two methods are important in evaluating the results of treatment.

To determine the severity of a scoliotic deformity as seen on the roentgenogram, there are three areas in the curve which must be considered in measurement. One is the center of the curve, the apex, and the others are the two ends of the curve, the upper and lower vertebrae. In orthopaedic parlance, the vertebrae corresponding to these areas are referred to as the apical vertebra and the upper and lower end vertebrae. The apical vertebra is the one at the center of the curve which shows the greatest displacement from the central plumb line and the greatest rotation and angulation. The end vertebrae are the uppermost and lowermost vertebrae which belong to the same curve as shown by their angulation or rotation, or both. Since the apex of the curve is always in the area of greatest deformity, it

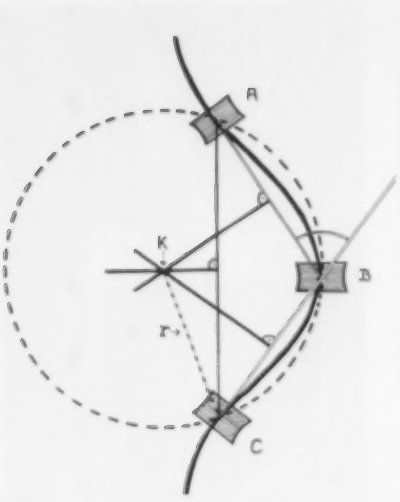



FIG. 1-A

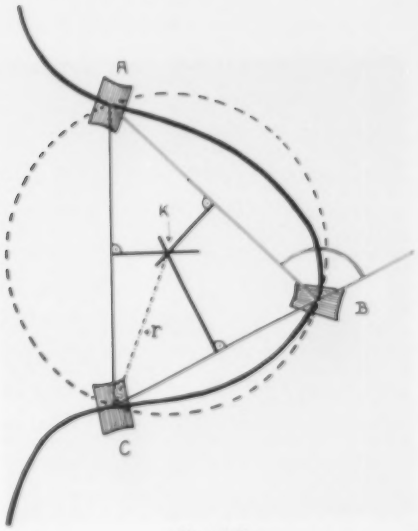



FIG. 1-B

Figs. 1-A and 1-B: Diagrams illustrating the common parabolic type of curve (Fig. 1-A) and the hyperbolic type of curve (Fig. 1-B) seen in severe scoliosis. Both curves correspond closely to the arcs, *ABC*, which are segments of circles drawn about the points, *K*, with radius *r*. The centers of the circles, marked *K*, are defined by the intersection of perpendicular lines through the mid-points of the sides of the triangles, *ABC*.

is the most laterally displaced part of the curve. Any true measure of the deformity must consider this portion of the curve, for the spinal curve does not resemble the curve in a bending steel rod in which the apex and ends move as one unit. The spinal curve consists of movable units which can move independently to some extent. Therefore, the ends of the spinal curve, which correct more easily than the central portion, may change without any associated alteration of the deformity of the vertebrae near the apex.

The curve to be measured on the roentgenogram may be considered as the arc formed by a curved line passing through the centers of the apical and end vertebrae. This curve may be a segment of a geometrically perfect circle, a parabolic curve (Fig. 1-A), as is commonly the case, or even a hyperbolic curve, as sometimes occurs in extremely severe deformities (Fig. 1-B). Thus, with any given curve, the arc passing through the center of the apical vertebra and the centers of the two end vertebrae can be described mathematically, regardless of whether the given curve is circular, parabolic, or hyperbolic.

By measuring the angle of the arc defined by these three principal vertebrae, a reasonably complete representation of the whole curve is obtained. Any subsequent change of the curve can be followed by measuring the angle of the corresponding arc which these three vertebrae define.

Both methods of measurement lose accuracy when overcorrection of the end vertebrae produces an exaggerated parabolic curve. In this situation, correction, or even overcorrection, of the end vertebrae is achieved without a proportional amount of correction at the apex of the curve. In Figure 2-C it can be seen that the end vertebrae have been overcorrected with the result that they have rotated around their horizontal anteroposterior axes, thereby changing the curve from an arc of a circle to a parabolic curve. Although both methods lack accuracy in this situation, there is a great difference in the measured amount of correction accord-

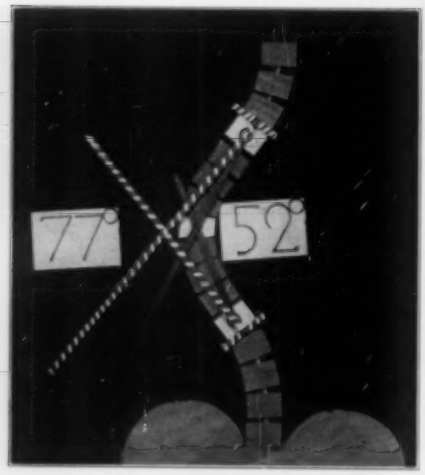



FIG. 2-A

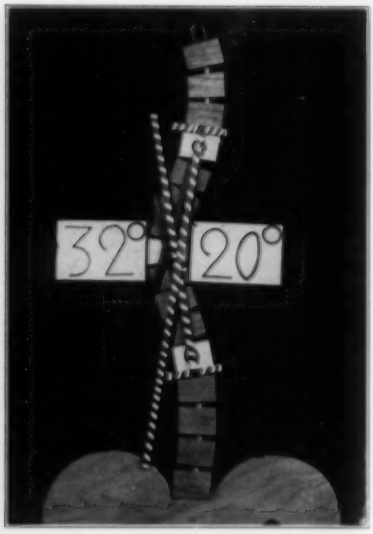



FIG. 2-B

Figs. 2-A and 2-B: Models illustrating the discrepancy in the results obtained in the measurements of correction of scoliosis by the Cobb method (method of perpendiculars) and the Ferguson method (method of the angle of the curve). Before correction (Fig. 2-A) the deformity is exaggerated by the Cobb method, which gives 77 degrees, as compared with 52 degrees by the Ferguson method. After correction (Fig. 2-B), because of overcorrection of the ends of the curve and rotation of the end vertebrae, the situation is reversed, with the Cobb method nowgiving a smaller value (20 degrees) than does the Ferguson method (32 degrees). In other words, 36 degrees more correction has apparently been obtained according to the Cobb method, but this difference is apparent and not real.

FIG. 2-C

FIG. 2-D

Roentgenograms before and after correction. Note that a negative reading of −10 degrees is obtained with the Cobb method as the result of rotation of the upper end vertebra, with consequent reversal of the inclination of its superior end plate.

ing to these two methods and, consequently, a discrepancy in the percentage of correction recorded. With the Cobb method the correction is 79 per cent, whereas with the Ferguson method it is only 60 per cent. The reason that the recorded correction is much less with the Ferguson method is because the three main vertebrae of the curve are considered in the measurement. With the Cobb method the result depends only on the surface inclinations of the end vertebrae. These inclinations may deviate considerably; they may become parallel to each other giving a zero reading, or even become reversed, thus giving a negative reading (Fig. 2-D). These points can be well illustrated in Figures 3-A and 3-B. These tracings of roentgenograms made before and after correction show overcorrection of the end vertebrae. According to the Cobb method, the curve was corrected from 35 degrees to 3 degrees, but it can be easily seen in the illustration after correction (Fig. 3-B) that in reality there is a much larger residual curve which measures 10 degrees with the Ferguson method.

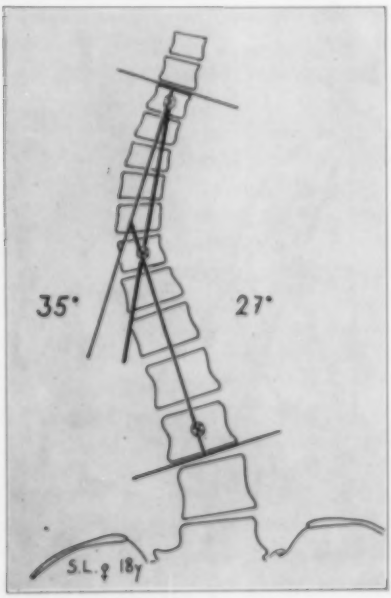



FIG. 3-A

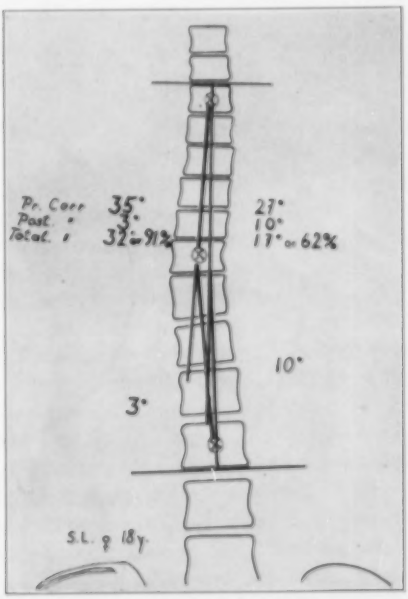



FIG. 3-B

Figs. 3-A and 3-B: S.L., female, eighteen years of age at the beginning of correction.
Fig. 3-A: Tracing of roentgenogram before correction.
Fig. 3-B: Tracing of roentgenogram made after correction. Note the differences in the results as measured by the two methods. This difference is brought about because overcorrection of the end vertebrae has occurred. This overcorrection has more effect on the measurement by the Cobb method than it does on the measurement by the Ferguson method.

Another manifestation of the difference between these two methods of measurement is the horizontal displacement of the apices of the measured angles during both progression and correction of the curve. When Cobb's method is used, the intersection of the perpendiculars moves toward the side of the convexity of the curve during progression of the curve and in the opposite direction during correction, but the amount of this displacement in either direction is not proportional to the corresponding displacement of the center of the curve because the directions of the perpendiculars that define the angle are dependent on the inclinations of the end vertebrae. These inclinations vary with the rotation of the end vertebrae during both progression and correction of the curve. Since this rotation, especially

if there is overcorrection, has no relation to the movement of the center of the curve there is no correlation between the position of the apex of the curve and the position of the intersection of the two perpendiculars.

With the Ferguson method, on the other hand, the apex of the measured angle always remains on the center of the curve. As a result, the lateral displacement of the apex of this angle is always proportional to the comparable displacement of the center of the curve.

The geometrical principles that govern the lateral displacement of the apices of the two measured angles are shown in Figure 4.

The actual curve is $ACB$, but the apex of the angle ($AC'D'$) formed by the perpendiculars $AC'$ and $BC'$ (Cobb method) does not correspond to the true center or apex of the curve $C$. In reality, these perpendiculars define a new arc $AC'B$, which is located to the right of the actual curve. This arc has the same chord $AB$ but it is the arc of the circle $AC'B$, and the height $HC'$ is nearly twice the distance $HC$. Therefore, arc $AC'B$ and arc $ACB$ possess the same chord $AB$ but the distances, $HC'$ and $HC$, are different and geometrically the two arcs are por-

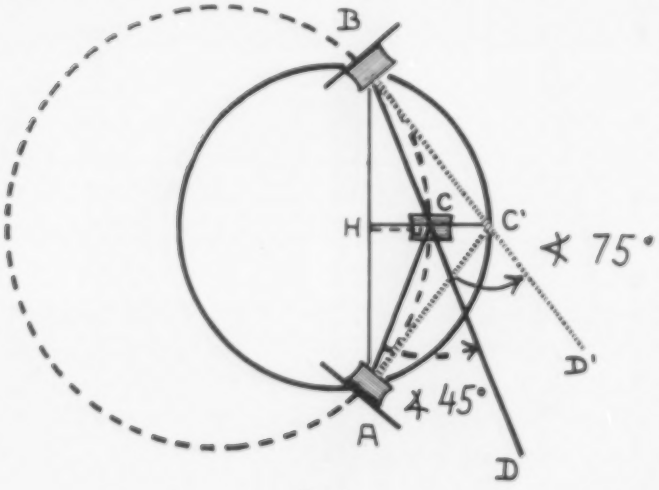



FIG. 4

Diagram showing the different locations of the apices of the measured angles by the Ferguson method ($ACB$) and the Cobb method ($AC'B$). See text for explanation.

tions of two completely different circles, or in other words, two different curves. The importance of the difference between these two arcs $ACB$ and $AC'B$ is apparent. Angle $ACD$ is 45 degrees and angle $AC'D$ is 75 degrees. The more eccentric the apex of the angle formed by the perpendiculars is to the apex of the curve, the larger will be the angle measured. Similarly, the less eccentric this apex, the less will be the angle measured. Thus, the angle formed by the perpendiculars does not measure the actual curve. In the treatment of scoliosis, if the results of treatment are to be accurately evaluated the whole curve and the progress of this curve must be measured and not the inclination or wedging of particular units in the curve or arch.

The displacement of the center of the curve may be measured in another way (Figs. 5-A and 5-C). In this method, a line is drawn between the centers of the end vertebrae, and a perpendicular is drawn from the center of the apical vertebra to this line. The length of this perpendicular is directly proportional to the meas-

ured angle obtained by the Ferguson method, and the measurement is consistent in comparable roentgenograms of the same curve. In Figures 5-A and 5-C, which are tracings of comparable roentgenograms made before and after correction, the distance from the apex to the line joining the centers of the end vertebrae changed from 4.7 centimeters to 2.2 centimeters, making a correction of 53 per cent. Using the Ferguson method, the correction was from 46 degrees to 20 degrees for a correction of 56 per cent. With comparable measurement using the Cobb method, the distance from the apex of the angle to the line joining the centers of the end vertebrae changed from 7.7 centimeters to 2.2 centimeters, a correction of 70 per cent, and the angular measurement changed from 70 degrees to 20 degrees, also a correction of 70 per cent. The displacement of the apex of the measured angle using the Cobb method is thus considerably more than the actual displacement of the center of the curve. The change in the angle formed by the perpendiculars is not a true representation of the correction of the curve, and the horizontal displacement of the apex of this angle does not correspond to the positional changes of the apex of the curve.

The method of measuring the displacement of the center of the curve described here is a simple and accurate way to follow the increase or decrease of a scoliotic curve.

The difference in the result obtained by the Cobb method and the Ferguson method during correction of a curve are illustrated in Figures 5-A through 5-D. Before correction, the curve is exaggerated when measured by the Cobb method. As correction progresses, this exaggeration decreases as the intersection of the perpendiculars moves toward the concave side. If the correction continues, the measurements by the two methods becomes identical when the two pairs of lines can be superimposed (Figs. 5-C and 5-D). With further correction beyond this point, the measurements again differ because the point of intersection of the perpendiculars continues to move more rapidly than the apical vertebra, with the result that the intersection is displaced toward the concave side ahead of the center of the apical vertebra (Fig. 5-B).

Subjective errors in measurement can occur with either method. The accuracy depends on how exactly the points or lines used in measurement are defined. Certainly, a great deal depends on the skill and experience of the physician who is using the particular method. To us it seems more accurate and easier to determine the center of a vertebra in a given roentgenogram than to draw lines along the poorly defined superior or inferior surface. The margin of error that we have found using the Ferguson method is from 1 to 3 degrees. In this method, the center of the vertebra can be determined by measuring its width, thus reducing the subjective error to practically zero. We have not been able to achieve such objective control when attempting to draw the lines parallel to the superior and inferior surfaces of the end vertebrae.

It is difficult to recognize an error as the lines are drawn along the poorly defined upper and lower surfaces of the end vertebrae since the exact plane of these surfaces is often made indistinct by the outlines of the vertebral bodies. Any error so caused is more obvious when the lines parallel to the surfaces of the end vertebrae are extended and the perpendiculars are drawn to form the angle to be measured (Fig. 6).

## DISCUSSION

When these two methods of measuring scoliotic curves of the spine are studied and compared, the differences and discrepancies between them are obvious. For a better understanding of these differences the following analysis is offered. Both methods have certain features which make them more or less inaccurate. Over-

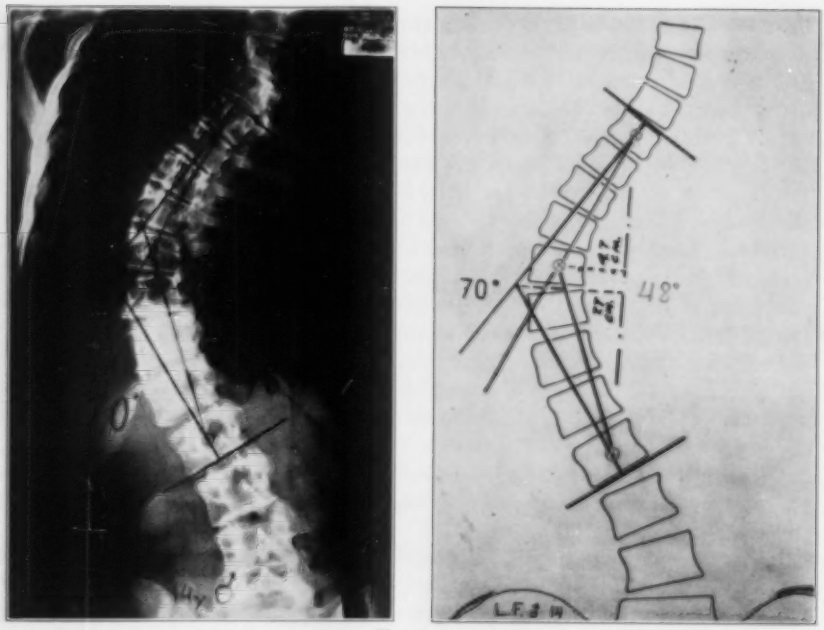



FIG. 5-A

Figs. 5-A through 5-D: L.F., male, fourteen years of age, anteroposterior roentgenograms and tracings before, during, and after treatment.

Fig. 5-A: Roentgenogram and tracing of roentgenogram before correction showing the displacement of the apex of the angle measured by the Cobb method beyond the center of the curve toward the convex side.

correction of the ends of the curve will cause errors in both methods, especially if an exaggerated parabolic curve is obtained after correction. However, this will have much less influence on measurements by the Ferguson method because the ends of the curve are aways considered in relation to the apex (apical vertebra) and the rotation of the end vertebrae around their anteroposterior axes cannot affect the measurements.

In comparing the measurements of correction given in Table I and illustrated in Figures 3-B, 5-C and 5-D, it is noted that with the Cobb method more correction is obtained. This of course means that the percentage of correction measured by this method will be greater than that obtained with the Ferguson method, although the actual amount of correction is the same. The importance of this discrepancy in clinical discussions and statistical reports is obvious.

This tendency of the Cobb method to magnify the curve as it progresses should be considered an advantage in clinical practice when small scoliotic curves are being followed and early detection of an increase will lead to earlier treatment.

If there were some mathematical relationship between these two methods, a correction factor could be used, and the discrepancies between the two methods would not cause a problem. Unfortunately, no such factor exists, since, in the Cobb method, the measured angle is determined only by the ends of the curve. The lines perpendicular to the surfaces of the end vertebrae define what we have termed *the angle of perpendiculars*, which, in reality, is a measure of the inclination of the end vertebra. This method is well suited to the measurement of segmental and intersegmental angulation or of the wedging of adjacent vertebrae within the curve, provided that overcorrected vertebrae are not included. This method could be used well for measuring anterior wedging in kyphosis.

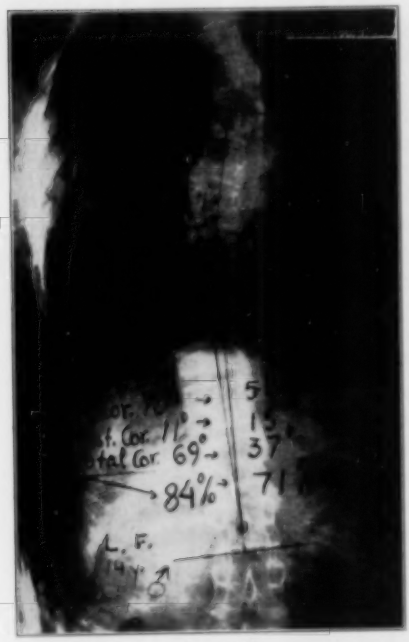



FIG. 5-B

FIG. 5-C

Fig. 5-B: Roentgenogram showing maximum correction obtained. The apex of the angle measured by the Cobb method has now moved beyond the center of the curve toward the concave side.

Figs. 5-C and 5-D: Roentgenogram and tracing after correction, showing some loss of correction while the patient was in the plaster jacket. The apex of the angle measured by the Cobb method now overlaps the center of the curve. The angle measured by both methods is the same.

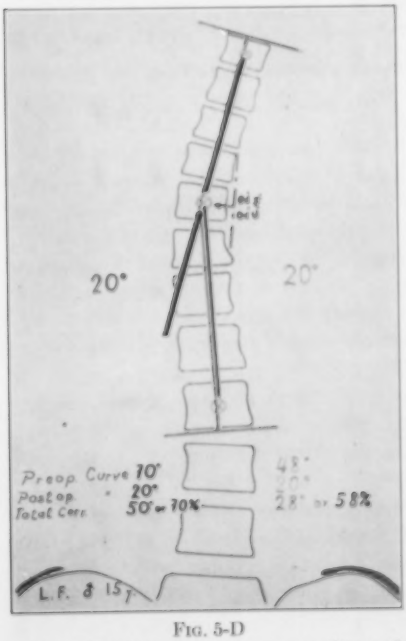



FIG. 5-D

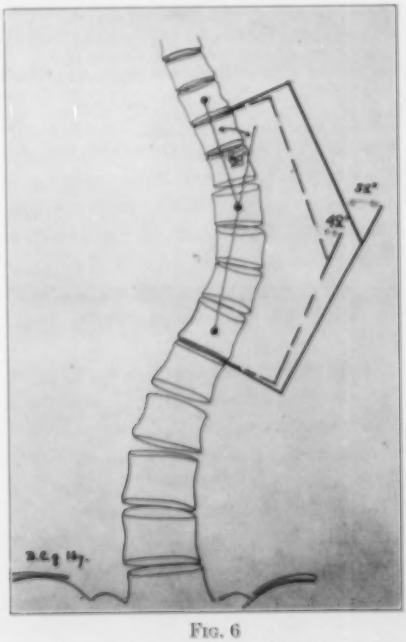


FIG. 6

Fig. 6: Tracing of a roentgenogram illustrating how an error may occur with the Cobb method. As shown here, differences of 5 degrees in the direction of each of the two lines supposedly parallel to the ends of the end vertebrae (broken and solid lines) cause an error in the measured angle of 10 degrees.

The angle formed by the Ferguson method is strictly related to all components of the curve, no matter what changes occur. This method measures changes in the curve with more consistent accuracy and, therefore, it seems justifiable to refer to it as *the angle of the curve.*

The margin of error in the Ferguson method is minimum, and, in our opinion, the proper points for measurement are easier and more accurately determined. With this method, overcorrection of the ends of the curve has the least possible influence on the results. Exaggeration of the curve before correction and exaggeration of the amount of correction after treatment are completely excluded. All in all, the Ferguson method seems to satisfy both the geometrical and clinical criteria for measuring lateral curvatures of the spine and is a very suitable method for use in comparative studies.

## CONCLUSIONS

The percentage of correction as determined by the Cobb method and the Ferguson method of measurement are not comparable. The differences and discrepancies between the two methods have been demonstrated and analyzed, showing the more favorable percentage of correction obtained by the Cobb method. When follow-up studies and end results are reported in the treatment of scoliosis, the method of measurement must be considered. Although both methods have their merits we have found the Ferguson method to be accurate. We believe it can be used by many orthopaedic surgeons with minimum, if any, error. Since this method depends on all the main components of the curve, it can be rightfully termed *the method of the angle of the curve.* A way of measuring the displacement of the apex of the curve toward the side of convexity of the curve has also been demonstrated as a simple and accurate way of following the progression or correction of a curve.

## REFERENCES

1. Cobb, J.R.: Outline for the Study of Scoliosis. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons. Vol. 5, pp. 261–275. Ann Arbor, J.W. Edwards, 1948.
2. Ferguson, A.B.: Roentgen Diagnosis of the Extremities and Spine. New York, Paul B. Hoeber, Inc., 1945.
3. Mau, Hans, and Kramer, W.G.: Grundlagen und Techniken der Skoliosenbehandlung in den USA. Arch. f. Orthop. Unfall.-Chir., **49:** 231–252, 1957.

# An Instrument for the Measurement of Oxygen Tension in Bone

## A Preliminary Report

BY CHARLES F. WOODHOUSE, M.D., CHICAGO, ILLINOIS

*From the Orthopaedic Department, Children's Memorial Hospital, Chicago*

A major problem in orthopaedic surgery today is the so-called unsolved fracture—subcapital fracture of the neck of the femur [2,4,6]. In about one-third of these fractures, disrupted blood supply causes avascular necrosis with anoxia and death of bone. This leads to failure of treatment and the patient faces further invalidism, surgery, and possible death. These hazards are greatest in the aged, who are most prone to this type of fracture. In an attempt to solve this pressing problem, an instrument has been designed on polarimetric principles—the Redox polarimeter. Its function is to determine, after fracture of the femoral neck, the oxygen tension within the head and thus enable the surgeon to determine the circulatory condition of the head of the femur and to choose the best treatment.

Phemister's statement is axiomatic: "Intracapsular fracture of the neck of the femur may, by injury of the blood supply, result in aseptic necrosis of a part or all of the head of the femur". Unfortunately, avascular necrosis of the femoral head has been impossible to detect until four to six months after fixation of the fracture and then only by evidence of roentgenographic changes. When this point is reached, the only recourse is some secondary reconstructive procedure, which holds considerable risk for the elderly patient already weakened by months of invalidism.

The mortality after reduction and fixation of hip fractures is known. In a report of the Fracture Committee of The American Academy of Orthopaedic Surgeons, the mortality is listed as 8.5 per cent [7]. The mortality rate after primary replacement arthroplasty has been reported as 14.9 per cent by Reynolds and as high as 17.7 per cent by Bascom and his associates. The mortality after secondary replacement procedures is not available in a comparable series, but by extrapolation it can be assumed to be much higher. Early detection of anoxia of the femoral head should be valuable in the estimation of the extent of avascular necrosis.

The original polarizable electrode was discovered by Kučera. Polarographic analysis was later developed by Heyrovsky. The technique makes possible accurate quantitative measurement of micromolar concentrations of electroreducible ions or compounds; it can be used as a rapid, precise electrical method for the determination of oxygen concentrations.

When a voltage is applied to two electrodes in a solution containing an electroreducible solute, such as oxygen, the resulting flow of current is directly proportional to the concentration of the reducible solute [10]. The specific reduction potential for oxygen at a platinum cathode, with reference to a silver anode, is −0.65 volt [10].

When this voltage is applied to electrodes in contact with tissue, the dissolved oxygen in the blood or tissue fluid is consumed at the electrode surface and replaced by oxygen diffusing from the tissue or nearby blood vessels. As oxygen is extracted from the blood, it is replaced by the dissociation of oxyhemoglobin. At normal atmospheric oxygen concentrations of 21 per cent, the dissolved oxygen in plasma is approximately 0.5 volume per 100 milliliters. The red cells,

however, contain, as oxyhemoglobin, approximately twenty volumes per 100 milliliters. If there is blood circulation to the area, the vast reserve of oxyhemoglobin maintains a measurable oxygen tension.

If the electrode is placed within the femoral head and the concentration of oxygen in the respired air is increased, the amount of oxygen dissolved in the blood and reaching the femoral head will increase. The time required for the concentration of oxygen in the femoral head to increase establishes a lung-hip oxygen circulation time.

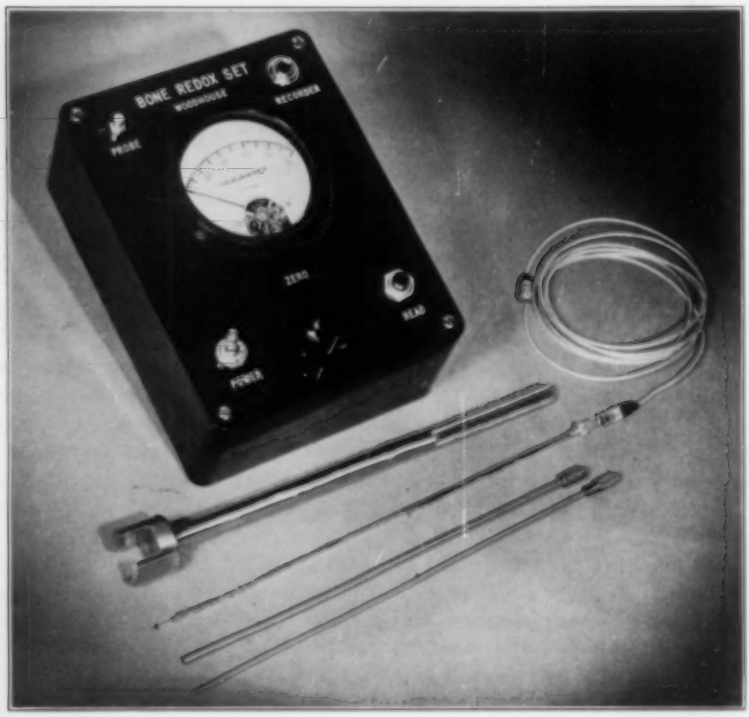



FIG. 1

The transistorized Redox polarimeter with (top to bottom) sterilizable control handle, nine-inch electrode probe and cable, and cannula and stylet for insertion into the head of the femur.

## EQUIPMENT

The apparatus includes the Bone Redox Set—a portable, self-contained transistorized polarimeter designed for the measurement of oxygen tension in bone—as well as a probe electrode, cannula, trocar, and cable with connections, all of which can be heat-sterilized or stored in 1:1000 aqueous zephiran hydrochloride. A detachable stainless-steel handle to fit over the polarimeter control knob is also supplied; the handle can be sterilized to enable the surgeon to adjust the instrument himself during the operation (Fig. 1).

The probe electrodes are concentric, consisting of an inner platinum cathode insulated from the outer silver anode by teflon (tetrafluoroethylene) insulation. The outer silver tube has the same diameter as the standard (3/32 of an inch) guide pin. The cable and connections are also insulated with teflon, so that both the probe and the cable can be heat sterilized. The cannula is made of stainless-steel tubing and fits over a 3/32 of an inch guide pin. During a hip-nailing proce-

dure, the cannula can be inserted into the femoral head over the initial guide pin; it can also be used with the trocar-pointed stylet which screws into the cannula with a left-hand thread. The cannula with its contained stylet can thus be drilled directly into bone without using a guide wire. The electrode fits inside both the cannula and the hole in the Smith-Petersen nail and other types of nail now available. The electrode can, therefore, be inserted through a nail at any time to check femoral-head oxygenation.

*Meter Circuit*

Simple in design, the meter circuit consists of a transistorized direct-current amplifier with high negative feedback for greater accuracy.

When the surgeon presses the *read* switch, an electromotive force of −0.65

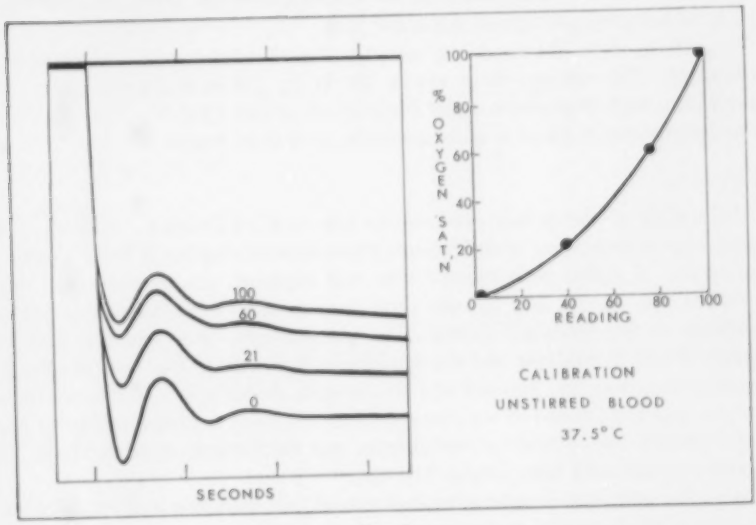



FIG. 2

Superimposed recordings of various oxygen tensions on the Sanborn visograph (left). Calibration curve with percentage of oxygen saturation in fresh heparinzed blood plotted against the polarimeter readings (right).

volt is applied to the platinum cathode. The resulting current is read out on a meter.

A reading is quickly and easily obtained, since a single control does two jobs: (1) it sets the instrument at calibration point *zero*, providing a norm from which to read, and (2) it sets the preadjusted sensitivity, thus providing an accurately calibrated scale. Once this single control is set, it needs no further adjustment. The oxygen analysis is thereafter automatic and the surgeon need only read the meter for oxygen percentage.

*Method of Checking the Instrument before Use*

When the instrument is turned on and set at calibration point *zero*, it is checked before surgery as follows:

1. A previously prepared, sterile ampule of 0.1 gram per 100 cubic centimeters of sodium sulphite [10] in 1:1000 aqueous zephiran chloride is opened;
2. The electrode is inserted into the ampule;
3. The surgeon presses the *read* button and obtains the zero meter reading;
4. A 250 cubic centimeter beaker containing two or three cubic centimeters

of saline solution is warmed to 37 degrees centigrade in a sterile warm-water basin;

5. The beaker's contents are swirled occasionally to equilibrate the solution with air—that is, saturate it with 21 per cent oxygen;

6. The electrode is now inserted into the warm saline solution;

7. The readout should indicate 21 per cent oxygen saturation.

The instrument is calibrated at 37 degrees centigrade because this is the body temperature of the patient—and of his hip—at surgery [11].

## DEVELOPMENT OF THE ELECTRODE SYSTEM

### *In Vitro*

The electrode system was tested *in vitro* by calibration in unstirred, fresh, heparinized human blood. Gas mixtures of nitrogen and oxygen, factory analyzed to ± 1 per cent, were bubbled for fifteen minutes through blood samples maintained at 37.5 degrees centigrade in a water bath.

Recordings were obtained one minute after bubbling was completed and discontinued. The voltage drop across the 0 to 100-milliampere meter was recorded on a high impedance input Sanborn visograph (Fig. 2). The calibration for this instrument in blood is quite accurate, as seen in Figure 2.

### *In Vivo*

Calibration of the polarimeter *in vivo* was next undertaken, with six adult mongrel dogs anesthetized with fifteen milligrams per kilogram of body weight of pentobarbital. A cuffed endotracheal tube was inserted; gas mixtures of helium and oxygen (20, 50, 80, and 100 per cent, in sequence) were delivered, without rebreathing, at ten liters per minute. The gas mixtures were checked with the Beckman Model D analyzer and the anesthesia flowmeters. The lateral aspect of the trochanteric area was exposed and the cannula drilled one inch into the bone. The stylet was then removed and the electrode inserted. A period of fifteen minutes per mixture was allowed for equilibrium, and the readings were obtained. The calibration agreed with that obtained *in vitro*.

After the calibration readings were obtained, the electrode and cannula were backed out of the bone and readings were obtained every two to three millimeters. During the withdrawal of the electrode, there were certain positions where it recorded increases in oxygen tension. These increased readings indicated that the electrode was near areas in bone where blood vessels were actively bleeding.

Active blood flow in bone mechanically decreases the diffusion zone from which the active electrode extracts oxygen and, by bringing more oxygen into this reactive zone, it increases the reading. Thus, a higher-than-normal electrode reading indicates active blood flow.

## EXPERIMENTAL SUBCAPITAL FRACTURES

To test the instrument further, six intracapsular osteotomies of the femoral neck were performed on adult mongrel dogs under pentobarbital anesthesia, fifteen milligrams per kilogram of body weight. The dogs breathed air at 21 per cent oxygen saturation.

### *Method*

The hip was exposed surgically, and a Gigli saw was passed intracapsularly around the femoral head. The electrode was then placed in the center of the femoral head under direct vision (Fig. 3). In all the dogs, the femoral heads had normal oxygenation when compared with the trochanteric region.

The femoral neck was then transsected with the previously placed Gigli saw,

but this caused no fall in oxygenation since the ligamentum teres is well developed in the dog and its circulation maintains a normal oxygen tension. When the femoral head was strongly twisted out of position in the acetabulum, occluding the blood vessels in the ligamentum teres, the oxygen tension fell rapidly to values at or near zero in all cases.

When the femoral head was released, normal circulation was restored with reoxygenation of the femoral head.

Finally, when the ligamentum teres was cut, with complete severance of the femoral head from its blood supply, there was total anoxia of the femoral head since the living but avascular bone extracted all available oxygen.

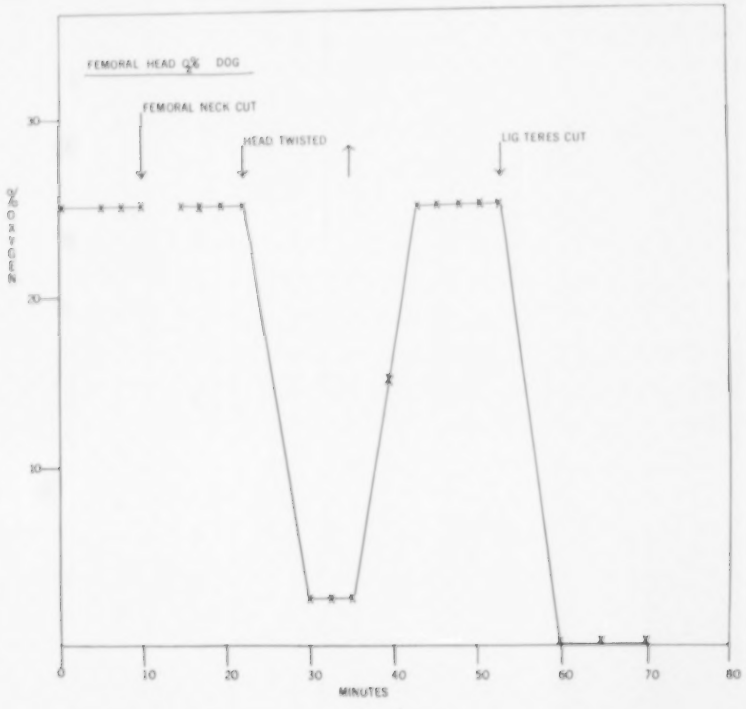



FIG. 3

Oxygen tension in the femoral head of a dog. The electrode is inserted, under direct vision, into the femoral head (1) with the femoral neck completely divided intracapsularly, (2) with the head twisted, and (3) with the ligamentum teres divided. The oxygen tension decreases as the blood supply is interrupted and cell metabolism and the electrode extract the available oxygen from the head. When occlusion is discontinued, the blood supply increases and oxygen saturation returns to normal. When the ligamentum teres is divided, the oxygen tension drops to zero.

## OBSERVATIONS IN THE HUMAN BEING

Once the polarimeter had proved itself by measuring bone-oxygen tension in experimental animals, the next step was to determine oxygen tension in normal human bone during procedures other than hip surgery.

In each of three patients, the electrode was introduced into cancellous bone under general anesthesia. A calibration was obtained with the use of gas mixtures similar to those used in the animal experiments. This calibration agreed with that obtained in both the *in vitro* experiment and the experimental animals. In two other patients, both breathing 80 per cent oxygen, polarograms were obtained in the calcaneus ten minutes after application of an arterial tourniquet to the thigh,

and again, ten minutes after release of the tourniquet. The effect of arterial occlusion was clearly recorded in the polarograms shown in Figure 4.

The polarogram is a graph depicting the flow of current against the applied electrode voltage. In this instance, polarograms were recorded with an RCA vacuum tube microammeter bridge. In this standard type of amperometric analysis, the slope of the curve is roughly proportional to the oxygen concentration. The polarogram obtained with the tourniquet on reflects the baseline or migrating-ion current values similar to those in oxygen-free blood. The zero reading for oxygen with tourniquet occlusion reflects the anoxia of the bone. Tourniquet release restored oxygen values to normal for 80 per cent respiratory oxygen.

## USES OF THE REDOX POLARIMETER IN HIP SURGERY

The Redox polarimeter was used in nineteen hips on which operations were performed. As shown in the table, measurement of the oxygenation in seventeen

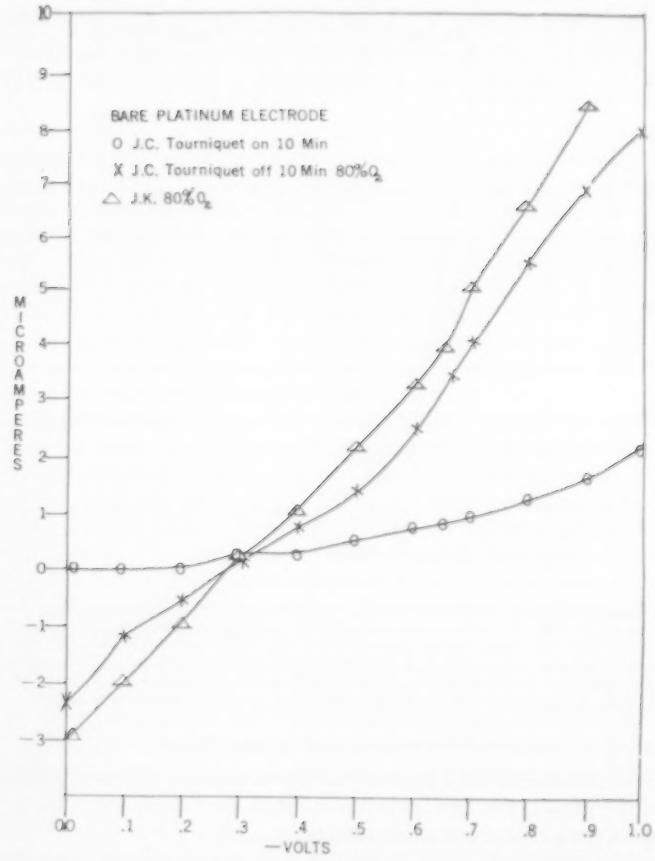



FIG. 4

Polarograms obtained during operation on two patients (J.C. and J.K.), both breathing 80 per cent oxygen. J. C. had a pneumatic tourniquet applied to the thigh. The baseline polarogram, obtained ten minutes after the inflation of the tourniquet, reflects the complete anoxia of the bone tissue. The polarogram on the same patient ten minutes after removal of the tourniquet shows a rise of current due to the appearance of oxygen in the tissue. The second high oxygen-tension polarogram, on J.K., was obtained with the same anesthesia and oxygen percentage.

TABLE I

RESULTS OF OXYGEN-TENSION MEASUREMENT WITH THE REDOX POLARIMETER

| | | | | Condition of Femoral Head as Determined by | | | |
|---|---|---|---|---|---|---|---|
| Patient | Fracture | Time to Operation | Operation | Oxygen Test | Microscopic Examination | Roentgenograms Six Months after Operation | Correlation |
| K.L. | Subcapital | 10 days | Arthroplasty | Dead | Dead | * | + |
| A.L. | Subcapital | 2 days | Arthroplasty | Dead | Dead | * | + |
| J.C. | Subcapital | 4 days | Pinning | Dead | * | Dead (5 mos.) | + |
| | Subcapital | 5 mos. | Arthroplasty | * | Dead | | + |
| I.L. | Subcapital | 2 days | Arthroplasty | Dead | Dead | * | + |
| C.W. | Subcapital | 3 days | Arthroplasty | Dead | Dead | * | + |
| L.K. | Subcapital | 8 days | Arthroplasty | Dead | Dead | * | + |
| E.S. | Subcapital | 9 days | Arthroplasty | Dead | Dead | * | + |
| L.D. | Subcapital | 1 day | Pinning | Alive | * | Alive | + |
| L.K. | Subcapital | 1 day | Pinning | Alive | * | Alive | + |
| L.M. | Subcapital | 2 days | Pinning | Alive | * | Alive | + |
| V.B. | Subcapital | 9 mos. | Nail removal | Alive | * | Alive | + |
| B.S. | Subcapital | 5 days | Pinning | Alive | * | Alive | |
| | Subcapital | 6 mos. | Nail removal | Alive | * | Alive | − |
| | Refracture ** | 10 mos. | Arthroplasty | * | Dead | | |
| R.J. | Intertrochanteric | 4 days | Pinning | Alive | * | Alive | + |
| V.Mc.C. | Intertrochanteric | 6 mos. | Nail removal | Alive | * | Alive | + |
| C.V. | Intertrochanteric | 1 yr. | Nail removal | Alive | * | Alive | + |
| T.H. | Intertrochanteric | 2 days | Pinning | Alive | * | Alive | + |
| D.T. | Intertrochanteric | 7 days | Pinning | Alive | * | Alive | + |
| B.M. | Intertrochanteric | 2 days | Pinning | Alive | * | Alive | + |
| C.A. | Slipped epiphysis | 7 days | Pinning | Alive | * | Dead | − |

* No reading or examination
** Eight months after first fracture

of these femoral heads correlated positively with results of microscopic examination or of roentgenographic examination at six months. In two hips there was no correlation. In one (Patient B.S.) there was normal oxygenation of the femoral head at the time of initial surgery. Six months later, when the fracture had healed, roentgenograms showed the femoral head to be viable, and the nail was removed. Two months later, the patient slipped and fell, refracturing the hip. When arthroplasty was performed two months later (ten months after fracture), the femoral head was dead. In the other (Patient C.A.) there was an acute, complete slipped capital epiphysis which was treated by reduction and internal fixation. At operation normal oxygenation was recorded, but subsequently avascular necrosis developed. In this case failure was due to technical error; the electrode was not placed in the femoral head.

Although the Redox polarimeter was used in this series only to collect data and not to help determine the best procedure, it seems clear, even at this point in its development, that this device is capable of doing so. Data are now being collected at several major institutions to provide substance for a definitive statistical study.

## DISCUSSION

The Redox polarimeter measures the availability of oxygen to the tissues directly in terms of oxygen tension. Thus, polarimetric analysis is a far more direct measurement of the circulation than the transport of substances to or from bone. Radiophosphorus uptake as a measure of circulatory adequacy may depend in part on tissue function. The differential uptake of $P^{32}$ between the femoral head

and the trochanter, as noted by Boyd and associates and by others[1,17], may indicate a difference in the physicochemical or metabolic activity of epiphyseal and metaphyseal bone; the uptake of $P^{32}$ may thus be influenced by this independent variable. In polarimetric measurement of oxygen tension this variable does not occur.

The measurement of venous clearance by the intra-osseous infusion of radiopaque media, as proposed by Hulth, presents certain technical difficulties. It cannot be used before the third day after surgery owing to leakage at the site of fracture; the cannula can be inserted only once and it must fit tightly into the femoral head to prevent leakage of the media. Hulth, however, noted some transfer of the media across the fracture, which may prove to be a strong argument for accurate reduction.

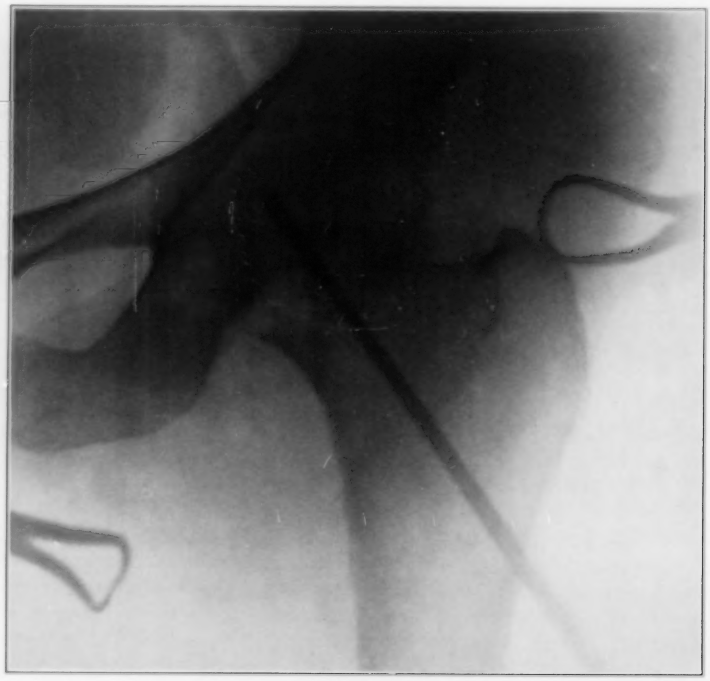


FIG. 5

Roentgenogram of a subcapital fracture with electrode in place at surgery. The original guide pin is inserted under roentgenographic control, the cannula is drilled up over the guide pin into the femoral head, the guide pin is removed, and the probe is inserted.

The measurement of clearance rates is of value in giving an index of circulation through the femoral head. The clearance of $Na^{24}$ from the femoral head, as reported by Laing and Ferguson, provides a direct measure of the adequacy of the circulation and eliminates unknown factors of tissue function.

The determination of bone-tissue-oxygen tension by polarimetric measurement can answer three questions which cannot be answered by any other method—and can answer them at once:

1. Is the bone oxygenation normal?

2. Is the lung-hip circulation time within normal limits, as indicated by the change in bone oxygenation with an increase in respired oxygen?

3. Is oxygenation uniform throughout the femoral head, as determined during withdrawal of the probe and by insertion of the probe in different areas, or is it patchy, indicating areas of infarction?

Boyd and associates and others [1,17] reported radioautographs showing segmental infarction of the superior weight-bearing portion of the femoral head. This may be related to disruption of the superior lateral epiphyseal artery [16] and to the localized collapse of the superior weight-bearing portion of the femoral head. This type of avascular necrosis is seen, after months have elapsed, in united subcapital fractures which appeared viable on roentgenograms.

Smith noted, in clinical observations during replacement arthroplasty, that malposition of the femoral head occluded the blood flow. My experiments on dogs also showed precipitous reduction of bone oxygen tension associated with changes in position of the femoral head. It is highly probable that occluded blood flow and the consequent anoxia may be decisive factors in the fate of the femoral head.

*Possible Technical Errors*

There are possible errors in polarimetric analysis of oxygen tension, but either they are easily detected or they are caused by the presence of blood flow and hence are of no clinical significance.

Since body temperature is relatively constant, the temperature coefficient error is minimized. This variable can be eliminated by making comparative measurement of trochanteric and femoral-head oxygenation. Any increase in the reading due to blood flow past the electrode tip is of no consequence since in the femoral head this is a sure sign of circulating blood.

The error introduced by electrode inactivity can be minimized by thorough wiping of the electrode between readings, and eliminated altogether by making comparative measurements in the trochanteric bone and the femoral head.

With time, oxygen can diffuse into a completely devascularized, dead femoral head and produce an initial reading of 21 per cent. Subsequent readings, however, will fall to zero and remain there because the electrode exhausts the supply of local oxygen and there is no circulation to replace it. In such a devascularized femoral head, an increase of inspired oxygen to 100 per cent does not produce a corresponding rise in oxygenation, whereas a comparative measurement of the oxygenation of the trochanteric bone does show a rise corresponding to the 100 per cent inspired oxygen. The results obtained with this instrument indicate that the oxygen tension in normal bone, as derived from the calibration curve, is within ± 5 per cent of the tension of the inspired oxygen.

It appears now that the polarimeter technique may prove easier and more accurate than radioactive isotope or phlebographic techniques for the assessment of femoral-head circulation. However, the fractures treated by manipulation and internal fixation have not been followed long enough to exclude the possibility of aseptic necrosis developing as a late complication.

## SUMMARY

The Redox polarimeter has been designed to detect the presence of anoxia in the femoral head after fracture. By directly measuring bone-oxygen tension, the Redox polarimeter helps the surgeon to evaluate femoral-head circulation and thus to choose the best procedure.

In experimental animals and in surgical patients, the Redox polarimeter immediately revealed anoxia due to occluded blood flow. In nineteen hips operated on, seventeen showed positive correlation between the oxygen-tension measure-

ment and results of microscopic study or roentgenographic examination six months after surgery.

Further data on the applications of the Redox polarimeter in hip surgery are now being collected for statistical evaluation.

REFERENCES


1. Arden, G.P.: Radioactive Isotopes in Fractures of the Neck of the Femur. J. Bone and Joint Surg., **42-B**: 21-27, Feb. 1960.
2. Banks, Henry: Factors Influencing the Result in Fractures of the Femoral Neck. Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Miami Beach, Florida, January 11, 1961.
3. Bascom, John; Philipp, L. D.; Haglin, J. J.; and Reiley, R. E.: Use of Hip Prostheses in Fresh Fractures. Experience with Fifty-two Cases at the Minneapolis General Hospital. J. Am. Med. Assn., **169**: 1863–1866, 1959.
4. Boyd, H. B., and George, I. L.: Fractures of the Hip. Results Following Treatment. J. Am. Med. Assn., **137**: 1196–1199, 1948.
5. Boyd, H.B.; Zilversmit, D. B.; and Calandruccio, R. A.: The Use of Radio-Active Phosphorus ($P^{32}$) to Determine the Viability of the Head of the Femur. J. Bone and Joint Surg., **37-A**: 260–269, Apr. 1955.
6. Christopher, Kenneth; Howard, L.G.; Potter, T.A.; and Driscoll, A.J.: A Study of One Hundred and Four Consecutive Cases of Fracture of the Hip. J. Bone and Joint Surg., **35-A**: 729–735, July 1953.
7. Conwell, H.E.: Treatment of Fractures of the Neck of the Femur by Internal Fixation. Report of the Fracture Committee of The American Academy of Orthopaedic Surgeons. J. Bone and Joint Surg., **21**: 483–486, Apr. 1939.
8. Heyrovsky, J.: Polarographie, theoretische Grundlagen, praktische Ausführung und Anwendungen der Elektrolyse mit der tropfenden Quecksilberelektrode. Wien, Springer, 1941.
9. Hulth, Anders: Femoral-Head Phlebography. A Method of Predicting Viability. J. Bone and Joint Surg., **40-A**: 844–852, July 1958.
10. Kolthoff, I.M., and Lingane, J.J.: Polarography. Ed. 2. Vol. 1, pp. 19, 399, 416, 417. New York, Interscience Publishers, Inc., 1952.
11. Kučera, G.: Kučera's electrode discussed and illustrated by Heyrovsky [8], pp. 2 and 3.
12. Laing, P.G., and Ferguson, A.B., Jr.: Radiosodium Clearance Rates as Indicators of Femoral-Head Vascularity. J. Bone and Joint Surg., **41-A**: 1409–1422, Dec. 1959.
13. Phemister, D.B.: Fractures of Neck of Femur, Dislocations of Hip, and Obscure Vascular Disturbances Producing Aseptic Necrosis of Head of Femur. Surg., Gynec., and Obstet., **59**: 415–440, 1934.
14. Reynolds, F.C.: Preliminary Report of the Committee on Fractures and Traumatic Surgery on the Use of a Prosthesis in the Treatment of Fresh Fractures of the Neck of the Femur. J. Bone and Joint Surg., **40-A**: 877–886, July 1958.
15. Smith, F.B.: Effects of Rotatory Valgus Malposi'ions on Blood Supply to the Femoral Head. Observations at Arthroplasty. J. Bone and Joint Surg., **41-A**: 800–815, July 1959.
16. Trueta, J., and Harrison, M.H.M.: The Normal Vascular Anatomy of the Femoral Head in Adult Man. J. Bone and Joint Surg., **35-B**: 442–461, Aug. 1953.
17. Tucker, F.R.: The Use of Radioactive Phosphorus in the Diagnosis of Avascular Necrosis of the Femoral Head. J. Bone and Joint Surg., **32-B**: 100–107, Feb. 1950.

# The Effect of Beryllium on Bone

## A Morphological Study of the Progressive Changes Observed in Rabbit Bone *

BY PATRICK J. KELLY, M.D., JOSEPH M. JANES, M.D., AND LOWELL F. A. PETERSON, M.D., ROCHESTER, MINNESOTA

*From the Section of Orthopedic Surgery, Mayo Clinic and Mayo Foundation, Rochester*

Since Gardner and Heslington's original report, the induction of osteogenic sarcoma in the rabbit with beryllium has been reported frequently [3,4,5,8,10,11,16,21,29]. Publications by Downs and by Wentz and associates and reviews of the literature by Sachs and Ballentine and by Hutchinson and associates provide an extensive bibliography concerning the action of beryllium on bone in animals and *in vitro*.

Interest in the toxic effects of beryllium on bones of the rabbit has been evident at the Mayo Clinic since 1952 [15,19,20,21,22]. Having devised methods that enabled us to obtain consistent reproducible changes in rabbit bone, we thought it pertinent to present the morphological findings observed.

### MATERIALS AND METHODS

*Preparation of the Material for Injection*

The preparation of zinc beryllium silicate we employed was suggested by Vorwald and was as follows: The dry material was ball-milled for four weeks and portions were weighed and worked into suspension in physiologic saline solution, the latter being accomplished by using a rubber policeman. Subsequently, the suspensions were sterilized in the autoclave at fifteen pounds of pressure for one hour. The size of the particles was one to three micra, as we reported previously [15].

With respect to experimental protocol, we followed Vorwald's suggestions, namely (1) work with a very dilute suspension, (2) keep the suspension sterile and in the refrigerator between injections, (3) shake the suspension vigorously to obtain a uniform distribution of the particles, and (4) inject slowly according to the tolerance of the animal.

Our actual technique of injection was as follows: five milliliters of a 1 per cent suspension of zinc beryllium silicate was injected into an ear vein of each rabbit twice a week for ten weeks. At the end of this time, each animal had received a total of one gram of zinc beryllium silicate, or 33.6 milligrams of beryllium expressed as the oxide.

*Rabbits Studied*

Fourteen rabbits were studied and are the basis of this report. As stated in previous reports [20,22], if the material for injection is prepared as just described, if the rabbits are splenectomized prior to injection, and if injections are made as described, changes in bone are produced in all rabbits if they live long enough (Table I).

In the period between completion of the injections and death of the animals, roentgenograms of the entire rabbit were made twice a month in all fourteen animals. From these roentgenograms, we were able to time the appearance of

* The study on which this report is based was supported in part by the Orthopaedic Research and Education Foundation and Grant No. C-4257, National Institutes of Health.

TABLE I

EFFECT OF INJECTION OF BERYLLIUM ON BONE IN FOURTEEN RABBITS

| Medullary Bone Formation | | | Osteogenic Sarcoma | | | |
|---|---|---|---|---|---|---|
| Rabbit | Week Appeared after Last Injection | Bones Affected | Week Appeared after Last Injection | Bones Affected | Bones Studied by Microradiography and Conventional Histological Methods | Week of Death or Sacrifice following Last Injection |
| 1 | 14 | Tibiae, humeri, and femora | 44 | Left ischium; left tibia, proximal epiphysis | Right tibia, metaphysis and epiphysis | 48 Died |
| 2 | 13 | Tibiae, humeri, and femora | No tumor present at necropsy | | Diaphysis of right humerus, and right femur | 40 Died |
| 3 | 8 | Tibiae, humeri, and femora; left ischium | 40 | Right humerus, proximal epiphysis; left femur, distal epiphysis | Right humerus, metaphysis and epiphysis | 49 Killed |
| 4 | 13 | Femora, tibiae, and humeri | No tumor present at necropsy | | Metaphysis of right humerus and right femur | 28 Died |
| 5 | 13 | Humeri, femora, and tibiae | No tumor present at necropsy | | Left humeral junction, diaphysis and metaphysis | 42 Died |
| 6 | 15 | Femora, tibiae, and humeri | 40 | Right ischium | Right femur, diaphysis | 44 Died |
| 7 | 9 | Humeri | 36 | Right humerus, proximal epiphysis | Right humerus, proximal metaphysis | 50 Killed |
| 8 | 11 | Humeri, tibiae, and femora | 32 | Left humerus, proximal epiphysis | Left humerus, diaphysis | 42 Died of tumor |
| 9 | 16 | Humeri and tibiae | 44 | Proximal epiphyses of left humerus, right femur, right and left tibiae; both ilia, and right, ischial tuberosity | Right femur, proximal epiphysis | 48 Died |
| 10 | 10 | Tibiae and femora | 52 | Left tibia, proximal epiphysis | Left femur | 57 Died |
| 11 | 16 | Femora, humeri, and tibiae | 30 | Right ilium; right humerus, proximal epiphysis | Femora | 36 Killed |
| 12 | 16 | Femora and humeri | 40 | Right femur, distal epiphysis; left ilium | Femora | 42 Killed |
| 13 | 15 | Femora, tibiae, and humeri | 40 | Right femur, proximal epiphysis; left ilium | Humeri | 43 Killed |
| 14 | 15 | Humeri and femora | None found at necropsy | | Femora | 40 Killed |

medullary bone and osteogenic sarcoma and observe their development. Necropsies were performed to confirm the roentgenographic observations.

Table I summarizes the protocols by giving the week that endosteal formation of bone (medullary bone) was first noted roentgenographically, the first appearance of a destructive lesion indicative of osteogenic sarcoma, the bones so affected, and the date that the rabbits died or were killed. In the past, our usual method was to inject beryllium into rabbits in groups of ten, but because of observations in the first ten rabbits used for this study we killed four rabbits (Rabbits 11 to 14, Table I) from a subsequent series. We then injected the arterial trees of these four rabbits with a mixture of India ink and gelatin by a method described previously [14].

Table I indicates the bones selected for study by microradiography and conventional histological techniques in rabbits 1 to 10 (six humeri, five femora, and one tibia). Roentgenograms were made of each of these bones individually, and the area selected for further study was marked on the roentgenogram. In this way we were able to orient the roentgenographic changes with the morphological findings and to relate the medullary-bone formation more easily to the osteogenic sarcoma when both occurred in the same bone. From these marked areas, two contiguous full-thickness sections of the entire bone were taken at right angles to the length of the bone. One section was two millimeters in thickness and the other one millimeter. The two-millimeter section was decalcified in 15 per cent formic acid and embedded in celloidin, and sections were prepared which varied in thickness from twelve to twenty micra [26]. The one-millimeter specimen was stored in absolute alcohol until it was prepared by the method of Frost: first it was ground to 100 micra and then to fifty micra in thickness. The ground sections were microradiographed at fifty and 100 micra. A General Electric CA-7 diffraction tube with a chromium target was used; the kilovoltage varied from ten to twenty and exposure time from ten to thirty minutes. We varied the exposure data to minimize artifacts. In essence, our methods were similar to those which we described before [25].

Particular bones were selected in the first ten rabbits on the basis of roentgenographic observations. We attempted to obtain areas of bone that would show medullary bone in close proximity to areas in which osteogenic sarcoma had developed later, areas that would show the medullary lesions that had appeared in the roentgenograms and had remained unchanged until death of the animal, and, finally, other areas in which the medullary bone had continued to progress and had obliterated the medullary cavity.

In rabbits 11 to 14 a mixture of India ink and gelatin was injected into the arterial trees, and serial sections, one centimeter thick, were prepared. These were taken from both femora in three rabbits and from the humeri of one rabbit. These serial sections were cleared by the method of Spalteholz, and the vessels were studied under the dissecting microscope.

## FINDINGS IN GENERAL

Two specific changes were noted in the roentgenograms of the fourteen rabbits:

1. Medullary formation of bone was detected by roentgenogram between eight and sixteen weeks (Table I) after the last injection of zinc beryllium silicate in all fourteen animals. These changes were seen in the diaphysis and proximal metaphyseal region of the tibiae, humeri, and femora, and, in one instance, in the ischium.

2. The other change was the sudden appearance of a destructive osteogenic

FIG. 1-A FIG. 1-B FIG. 1-C

Figs. 1-A, 1-B, and 1-C: Distal portion of the rabbit humerus.
Fig. 1-A: Just before injection of zinc beryllium silicate.
Fig. 1-B: Eighteen weeks after injection. New bone is being laid down on the endosteal surface in the proximal metaphysis.
Fig. 1-C: Appearance at time of sacrifice. Arrow indicates site of selection of sections for histological and microradiographic study.

FIG. 2-A FIG. 2-B FIG. 2-C FIG. 3-A FIG. 3-B

Figs. 2-A, 2-B, and 2-C: Filling in of the medullary cavity of the rabbit femur.
Fig. 2-A: Two months after injection, the first changes are seen.
Fig. 2-B: Five and a half months after injection, the changes are more evident.
Fig. 2-C: At twelve months after injection, the medullary cavity is almost entirely converted to bone.
Figs. 3-A and 3-B: Roentgenograms of rabbit tibia.
Fig. 3-A: Well developed medullary bone deposition three and a half months after injection.
Fig. 3-B: At eleven months entire upper end of the tibia is filled in with the dense medullary bone. Arrow marks site of sections in Figs. 6-A and 6-B.

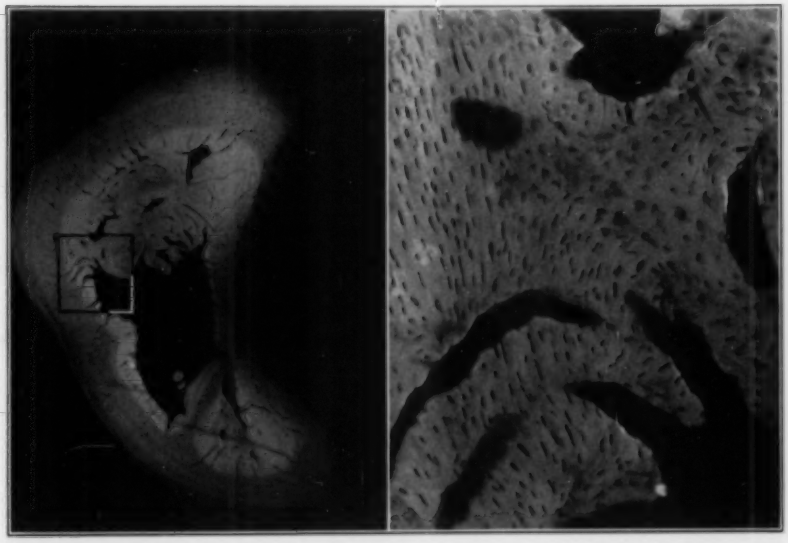


FIG. 4-A FIG. 4-B

Figs. 4-A and 4-B: Bone at site of arrow in Fig. 1-C.

Fig. 4-A: This section illustrates the way the more highly mineralized abnormal medullary bone is laid down on the endosteal surface of the cortex (microradiogram: 20 kilovolts, 15 minutes, chromium target tube, × 13).

Fig. 4-B: Higher-power view of bone at junction of cortical and abnormal medullary bone (site is indicated by square in Fig. 4-A). Some lacunae are sharp and distinct, whereas others are blurred as if the lacunar spaces are being filled with mineral (microradiogram: 20 kilovolts, 15 minutes, chromium target tube, × 112).

sarcoma between the thirtieth and fifty-second week after the last injection in ten of the fourteen animals. The osteogenic sarcoma was observed in the proximal portions of the tibia and the humerus, in the distal and proximal portions of the femur, or in the ischial tuberosities and iliac crests in these ten animals. Our previous work indicated that both medullary bone and osteogenic sarcoma will develop if the rabbit lives long enough [20,22].

## MEDULLARY FORMATION OF BONE

### *Roentgenographic Changes*

Eight to sixteen weeks after completion of the injections, roentgenograms revealed that bone was being deposited on the endosteal surface of the cortex (Figs. 1-A, 1-B, 2-A, and 3-A). In an occasional long bone, just a thin circumferential layer of new bone would be deposited on the inner aspect of the cortex. The process would then cease approximately eighteen weeks after the last injection and would remain unchanged roentgenographically until death of the rabbit. In the distal portion of the left humeral diaphysis of rabbit 5, medullary formation of bone was noted in the roentgenograms thirteen weeks after the injection, but no further increase occurred at eighteen weeks or later after the last injection (Figs. 1-A, 1-B, and 1-C). In nearly all instances the bone would continue to form and would fill the entire medullary cavity at the time of death of the rabbit (Figs. 2-A through 3-B).

### *Microradiographic and Histological Changes (Figs. 4-A through 9-D)*

#### *Increased Mineral Content of Abnormal Endosteal Bone (Medullary Bone)*

Microradiograms of areas in the diaphysis and at the junction of the diaphysis

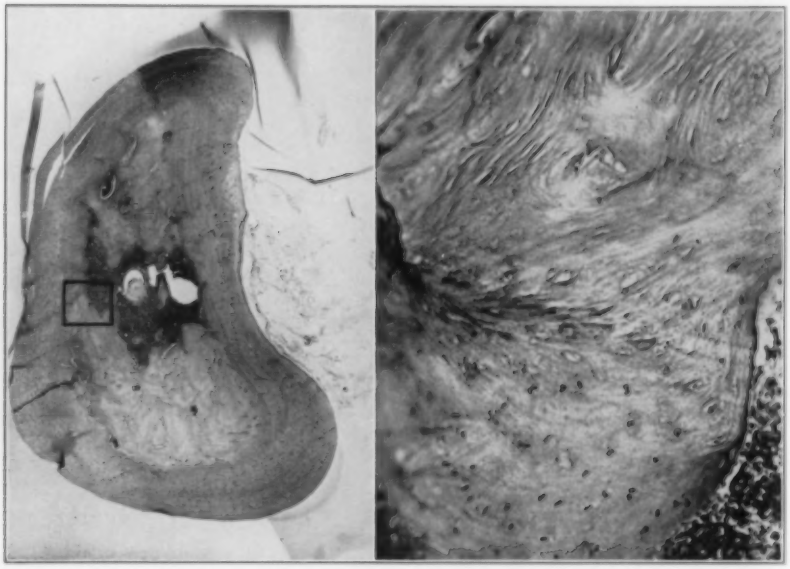


FIG. 5-A FIG. 5-B

Figs. 5-A and 5-B: Contiguous sections to Figs. 4-A and 4-B.
Fig. 5-A: Low-power magnification (hematoxylin and eosin, × 13).
Fig. 5-B: Higher magnification. The empty lacunae, devoid of cells with their nuclei, are oriented similarly to the blurred lacunae seen on the microradiogram in Fig. 4-B (hematoxylin and eosin, × 175).

and metaphysis revealed that the endosteal bone had a higher mineral content than the surrounding cortical bone (Fig. 4-A). Areas of higher mineral content show greater x-ray absorption.

In the parts of the long bones where cancellous bone was normally more prominent, the spaces between the normal-appearing trabeculae were filled with amorphous bone of higher than normal mineral content (Fig. 6-A). Contiguous histological sections revealed that this bone, lying between normal trabecular bone, stained more basophilically with hematoxylin and eosin (Fig. 6-B). The cells in this bone appeared to be normal and similar to the osteocytes seen in the nearby trabeculae (Fig. 6-C). This bone with high mineral content, altered staining qualities, and apparently normal cells did not exhibit as distinct a lamellar structure as did the normal-appearing surrounding trabecular bone.

*Indistinct Lacunae*

At higher magnification, the microradiograms revealed areas of indistinct lacunae in the abnormal medullary bone. The areas of indistinct or blurred lacunae were consistently seen in all sections of abnormal medullary bone. Microradiograms were obtained with various exposures and thicknesses of the sections of undecalcified bone. Figures 4-B, 7-C, and 8-B show areas of indistinct lacunae adjacent to normal bone, whose lacunae by comparison are distinct and sharp.

Contiguous histological sections stained by hematoxylin and eosin were reviewed. In areas corresponding to the areas of blurred or indistinct lacunae, we observed that the bone was devoid of cells—in other words, the lacunae were just empty spaces (Figs. 5-B and 7-B).

*Distribution of Indistinct Lacunae*

Indistinct lacunae, seen by microradiography and their corresponding empty

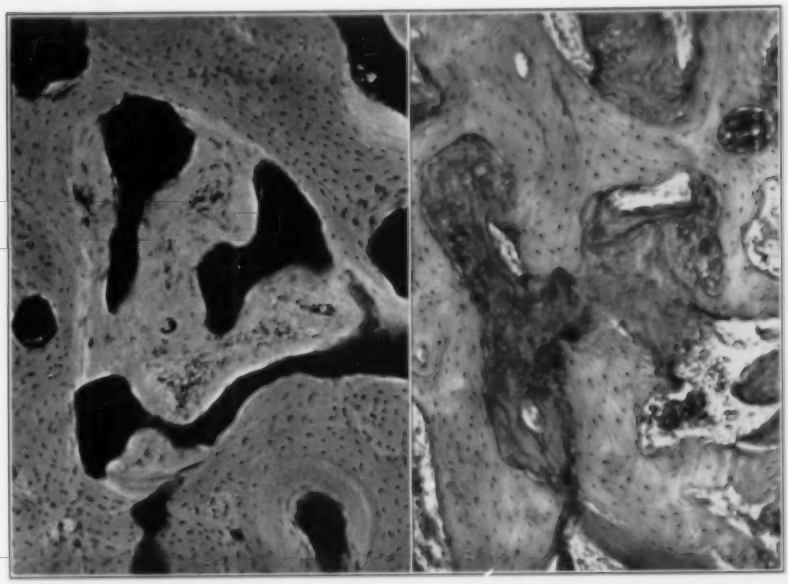


FIG. 6-A FIG. 6-B

Fig. 6-A: Hightly mineralized abnormal bone in the small marrow space is outlined by surrounding normal-appearing, less-mineralized trabecular bone (microradiogram: 20 kilovolts, 20 minutes, × 120).

Fig. 6-B: Contiguously oriented histological section. The abnormal bone lying between normal-appearing trabecular bone stained more deeply and lacked lamellar orientation (hematoxylin and eosin, × 120).

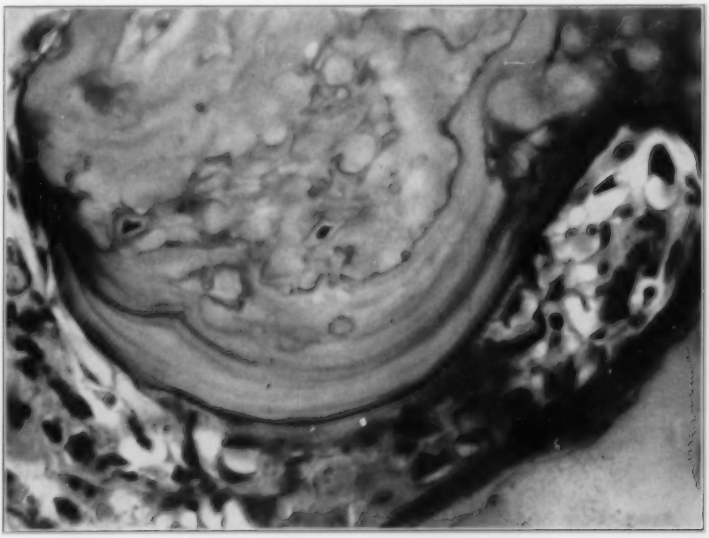


FIG. 6-C

Higher magnification of this abnormal bone. The cells appear normal (hematoxylin and eosin, × 675).

lacunae observed with conventional histological methods, were located in two areas of the abnormal medullary bone: first they were seen in the areas where medullary bone appeared by microradiography and routine histological methods to have a reduced medullary blood supply (Fig. 7-A). The second location, as

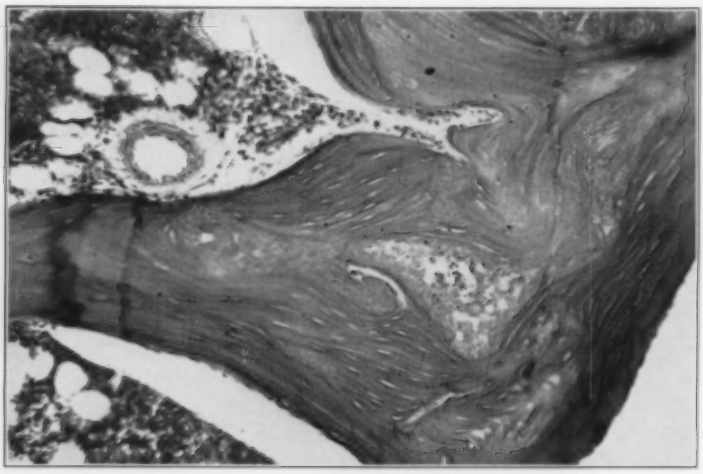


FIG. 7-A

A large arteriole and filling in of the intertrabecular spaces. Such an arteriole usually branches to supply trabecular bone, but filling in of the spaces may block such branching. A one-dimensional picture like this is not as helpful in evaluating vascular changes as are thicker sections like those shown in Figs. 9-A, 9-B, 9-C, and 9-D (hematoxylin and eosin, × 132).

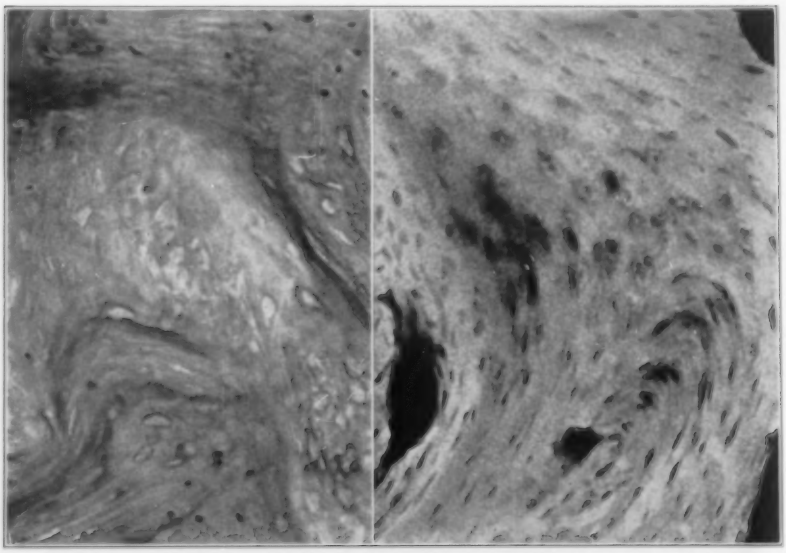


FIG. 7-B FIG. 7-C

Fig. 7-B: Higher-power view of an area similar to Fig. 7-A, where the deposition of the abnormal bone appears to have filled in the intertrabecular area and blocked incoming blood vessels. The lacunae in this bone are devoid of cells (hematoxylin and eosin, × 275).

Fig. 7-C: Microradiogram of contiguously oriented section. The lacunar spaces are indistinct due to partial mineralization of the lacunar spaces (× 175).

illustrated in Figures 8-A and 8-B, was in areas of cancellous bone where endosteal new bone was deposited on the existing trabeculae. In this new bone the lacunae were devoid of cells (Fig. 8-A). On microradiography, such lacunae were difficult

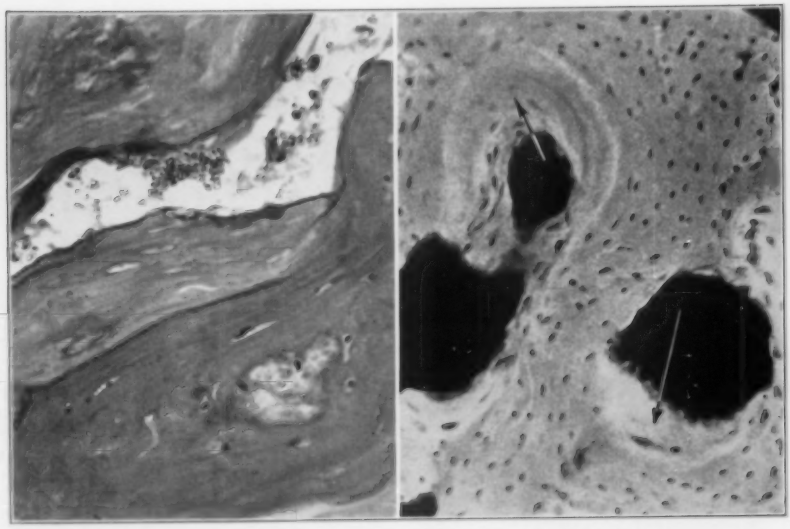


FIG. 8-A FIG. 8-B

Fig. 8-A: Endosteal new bone deposited on the existing trabeculum. This endosteal bone is devoid of cells with their nuclei. Crystals of zinc beryllium silicate are seen in the marrow space adjacent (hematoxylin and eosin, × 355).

Fig. 8-B: Microradiogram to illustrate the blurred lacunae or nearly erased lacunae on the edge of marrow spaces. Arrows illustrate this. The lacunae adjacent to these areas are clear (× 175).

to distinguish because they were indistinct (Fig. 8-B), but the areas of abnormal bone with indistinct lacunae seemed to be located adjacent to marrow spaces in which one could distinguish zinc beryllium silicate crystals in macrophages and lying free in the marrow spaces (Fig. 8-A). The crystalline particles in the marrow spaces were identical to the particles observed in the zinc beryllium silicate suspension as shown by microscopy with transmitted and polarized light. Barnes made similar observations concerning the presence of zinc beryllium silicate crystals in marrow spaces.

*Effect of Medullary Bone Formation on Blood Supply*

Because of the observation that medullary formation of bone might affect blood supply, we decided to kill four rabbits from a second series and study serial one-centimeter sections of bone after injection of the arterial tree with a mixture of gelatin and India ink. The blood supply to long bones of rabbits was described by Brookes and Harrison and by Morgan. Studies conducted in our laboratory tended to confirm their observations. The normal circulatory pattern in the diaphysis of a rabbit femur is illustrated in Figures 9-A and 9-B. The nutrient artery gives rise to transverse or lateral medullary branches which enter the cortex. The vascular pattern generally is similar to that seen in any long bone, regardless of species. When medullary formation of bone occurs in a section of diaphyseal bone, as illustrated in Figures 9-C and 9-D, the transverse or lateral branches from the nutrient vessels are encroached upon by this abnormal medullary bone. It is even apparent from our study that the main nutrient vessels may be encroached upon as well.

At a higher magnification, Figures 7-A, 7-B, and 7-C demonstrate the type of arteriolar vessel that branches and rebranches in and about trabecular bone to

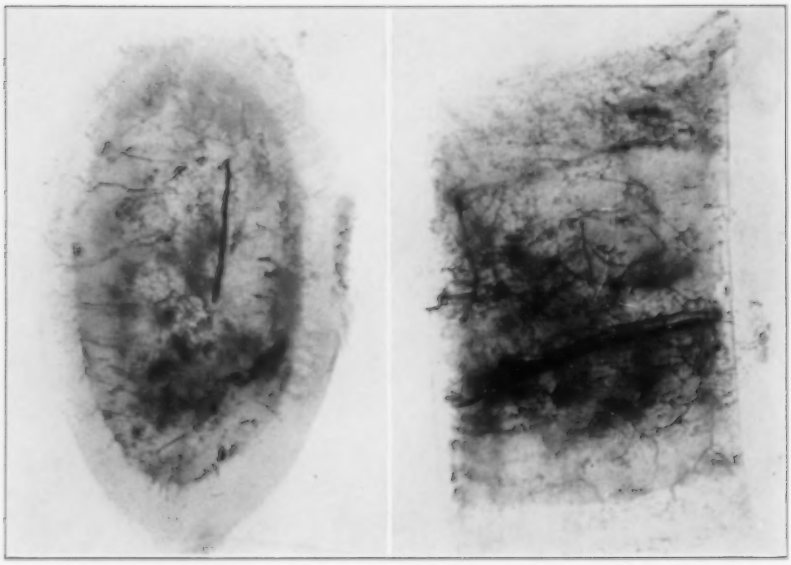


FIG. 9-A FIG. 9-B

Figs. 9-A, 9-B, 9-C, and 9-D: Sections of femora of the rabbit viewed under dissection microscope (India ink; 0.5 centimeter thick, × 10).

Figs. 9-A and 9-B: A normal vascular pattern in sections from a femur in which no medullary filling is noted.

Fig. 9-A: Branches pass from the centrally placed nutrient artery radially to the cortex

Fig. 9-B: Same section in longitudinal perspective.

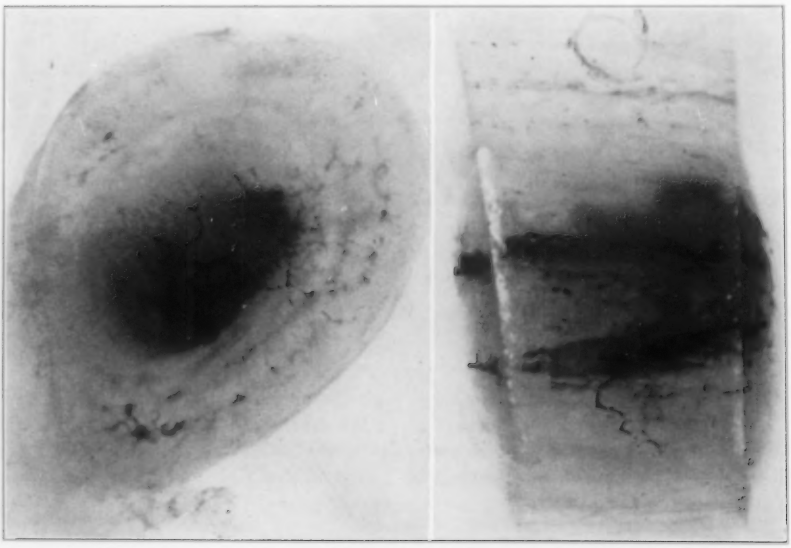


FIG. 9-C FIG. 9-D

Figs. 9-C and 9-D: Abnormal vascular pattern.

Fig. 9-C: Progressive encroachment upon the normal vascular pattern caused by the formation of the medullary bone.

Fig. 9-D: Same section as Fig. 9-C in longitudinal perspective.

FIG. 10-A FIG. 10-B FIG. 10-C

Figs. 10-A, 10-B, and 10-C: Rabbit femur in which a distinctive osteogenic sarcoma appeared eight months after injection of zinc beryllium silicate.
Fig. 10-A: Just before injection.
Fig. 10-B: Four months after injection.
Fig. 10-C: Eight months after injection. Arrow *X* points to area of osteogenic sarcoma and arrow *Y* to area of medullary bone formation.

supply it with blood. Here we observed that the intertrabecular space is filled with amorphous bone. Normally, a branch from such a large arteriole as that illustrated in Figure 7-A would branch again to enter the space filled with amorphous bone, but this branch is blocked by the medullary bone formed in the intertrabecular spaces (Fig. 7-B).

In summary, then, cleared specimens demonstrated a gradual isolation or encroachment of the nutrient vessels and their transverse or lateral branches by the abnormal medullary bone. Microscopically, the abnormal medullary bone deposited in intertrabecular spaces seemed to block areas where normally one would expect to see smaller vessels branch out to supply trabecular bone.

## OSTEOGENIC SARCOMA

### *Roentgenographic Changes*

The sarcoma produced by zinc beryllium silicate did not make its appearance until thirty to fifty-two weeks after the last injection (Figs. 10-A, 10-B, and 10-C). The changes indicative of osteogenic sarcoma were usually destructive—in some cases they produced bone. The tumors were seen at the epiphyseal-metaphyseal

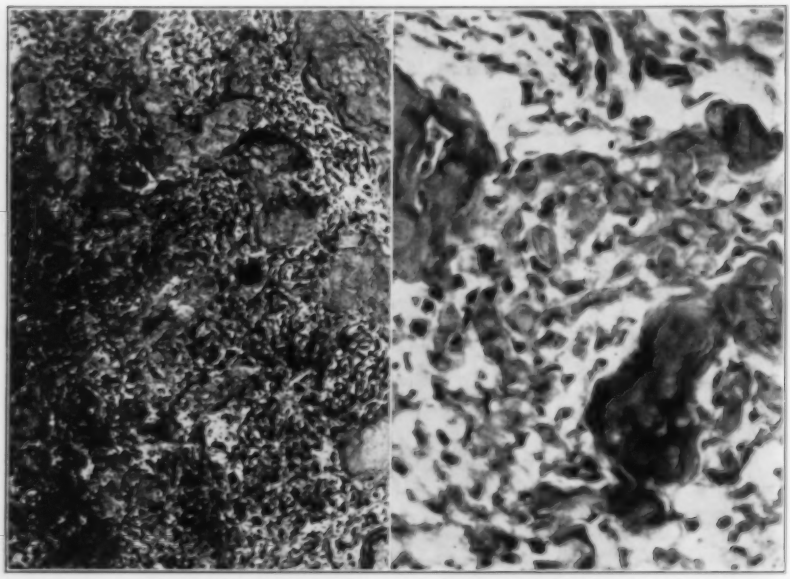


FIG. 11-A FIG. 11-B

Fig. 11-A: Low-power magnification to illustrate the anaplastic background in which the aggregates of tumor bone form (hematoxylin and eosin, × 110).

Fig. 11-B: Tumorous bone in small aggregates (hematoxylin and eosin, × 340).

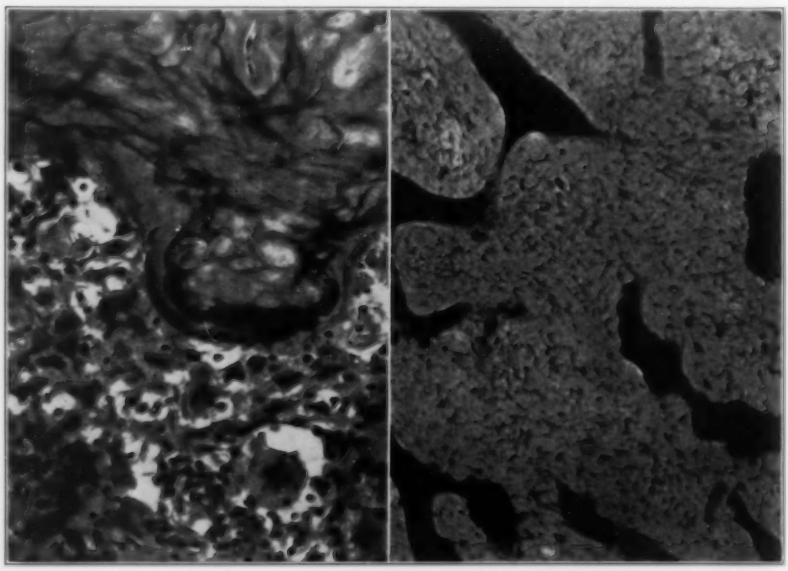


FIG. 11-C FIG. 11-D

Fig. 11-C: These aggregates seem to coalesce to form large masses of tumorous bone (hematoxylin and eosin, × 340).

Fig. 11-D: This tumorous bone is evenly mineralized. The lacunae are stellate-appearing as the cellular components seem squeezed by the piling up of mineralized tissue (microradiogram: 20 kilovolt, 10 minutes, × 120).

junction of long bones and also in such flat bones as the scapula and pelvis. Osteogenic sarcoma was not seen in the diaphyseal regions. The relation of osteogenic sarcoma to the medullary bone in the diaphysis is illustrated in Figure 10-C.

*Histological and Microradiographic Changes*

We noted three histological varieties of osteogenic sarcoma: osteoblastic chondroblastic, and fibroblastic. The type of osteogenic sarcoma observed in the present series is identical to that noted and illustrated previously [21,22]. It is usual to find all three varieties in the same tumor.

In addition to these observations, we noted that neoplastic bone formed in small aggregates in certain areas; and in other areas, these aggregates coalesced to form sheets of tumorous bone. Figure 11-A is a low-power photomicrograph to illustrate the background of anaplastic cells in which small aggregates of tumerous bone develop; Figure 11-B reveals these aggregates at higher magnification; Figure 11-C demonstrates the fusion of these aggregates into a larger mass of tumorous bone; and Figure 11-D reveals the coalescing areas of tumorous bone to be heavily mineralized. Comparison of these observations with a similar study on osteogenic sarcoma in man [17] revealed a marked similarity between beryllium-induced osteogenic sarcoma in the rabbit and osteogenic sarcoma in man.

Comparison of the morphological appearance of the abnormal medullary bone with that of osteogenic sarcoma indicates a clear difference. The abnormal medullary bone is not formed in a background of neoplastic tissue; the cells of the newly formed endosteal bone (medullary bone) appear, when seen, very similar to osteocytes (Fig. 6-C). In the abnormal medullary bone, anaplasia is absent; this is not the case, however, in areas where tumorous bone (osteogenic sarcoma matrix) is present. In medullary bone there are many areas where cells are absent from their lacunae in the sections stained by hematoxylin and eosin. In tumorous bone stellate cells are present in their lacunae and present sharp, clear outlines in the microradiogram; whereas in the earlier appearing endosteal bone, the lacunae in certain areas of the medullary bone are indistinct and blurred.

## COMMENT

One is limited in interpreting such morphological findings. Nonetheless, some interpretation of our data can be made in light of other investigations.

Beryllium is the agent producing these changes. This seems to be supported by our work and that of others. Barnes produced the tumor by using finely ground beryllium particles, and Dutra and associates [11] used beryllium oxide to produce it. In addition, we demonstrated by examination of the saline suspension of zinc beryllium silicate that the particles in the suspension and particles in the marrow spaces of the bone are identical when viewed through the microscope with transmitted light and polarized light.

The significance of the indistinct and blurred lacunae in the abnormal medullary bone, which, when stained with hematoxylin and eosin, are shown to be empty lacunar spaces, requires comment. We believe that this phenomenon is due to the absence of osteocytes in these areas. If cells in the medullary bone die, the lacunae would appear empty in histological preparations—this appears to have occurred in certain areas.

Mineralization of the lacunae subsequent to cellular death would provide a satisfactory explanation for the observed indistinct appearance of the corresponding area on the microradiogram.

A similar phenomenon was reported by Looney and by Rowland and associ-

ates in bones of radium-burdened human patients, by Jowsey in the aging human skeleton, and by Jee and Arnold in plutonium-poisoned beagles.

Why, however, do the cells apparently die? Perhaps two reasons could be offered. Cellular death may be due to the cytotoxic effect of beryllium ions on newly forming trabecular bone. Beryllium is a recognized cytotoxin [1,7,30,33]. Vorwald and Reeves summarized the action of beryllium on various intracellular enzyme systems and postulated that the biological effect of beryllium may be due to enzymatic derangements causing altered cellular function. As illustrated in Figure 9-A, we noted zinc beryllium silicate crystals in macrophages in the marrow spaces or lying free in the marrow spaces, as did Barnes. Whether the zinc beryllium silicate crystals actually lie free in the marrow space or have been left there by macrophages that died is beyond our knowledge. The very slow release of beryllium from the insoluble zinc beryllium silicate may produce a continuous low cytotoxic effect. Beryllium ions so released may then be excreted in the urine or perhaps redeposited as ionic beryllium in the bones and liver if we may accept the work of Allen and associates and Scott and associates on distribution and excretion of $Be^{7}$.

A second factor may be operative in cellular death. The vascularity of the areas showing the formation of medullary bone is definitely reduced. At the present stage of investigation, this decrease in vascularity seems to be due to the abnormal formation of bone; however, we still must keep in mind the distinct possibility that the abnormal formation of bone and decreased vascularity are coincidental phenomena and that the decreased vascularity may be due to the same cytotoxic effects as the abnormal formation of bone.

The appearance of osteogenic sarcoma at a later stage in the period of observation again may represent a continued cumulative effect from slowly released beryllium ions on the enzyme systems of the cells. Investigations by Chevremont and Firket in tissue culture indicated inhibition of cell growth and mitotic abnormalities caused by contact with beryllium ions.

The latent period between injection of the zinc beryllium silicate and the appearance of medullary bone or osteogenic sarcoma cannot be explained by such a study any more than it can be with similar studies of other tumorigenic agents, such as plutonium or radium, nor is it possible at the present time to compare the tumor-forming mechanism of beryllium with that of such radioactive elements as plutonium or radium.

## SUMMARY

A series of fourteen rabbits were studied by roentgenograms made twice a month after injection of zinc beryllium silicate. After death or sacrifice, twelve long bones from ten rabbits were studied by microradiography and celloidin-embedded contiguous sections stained by hematoxylin and eosin. Spalteholz preparations of bones from four additional rabbits were also studied after injection of the arterial tree with a mixture of gelatin and India ink.

The following observations were made: Medullary formation of bone was detected from the roentgenograms made eight to sixteen weeks after the last injection in all fourteen rabbits. Microradiography disclosed that this bone had a higher mineral content than the surrounding normal bone. In certain areas in this medullary bone, the lacunar spaces were blurred or indistinct on microradiography. Contiguous histological sections revealed that similar areas in sections stained by hematoxylin and eosin were devoid of cells. Therefore, it is postulated that the blurred lacunae evident in the microradiograms represent areas where the cells have died and mineralization of the empty lacunar spaces

has occurred. Part of this phenomenon may be due to the direct cytotoxic effect of the zinc beryllium silicate seen in marrow spaces adjacent to the apparently non-viable, acellular bone on the surface of viable trabecular bone. Also, this phenomenon may be due to a decrease in vascularity caused by blockage of the blood supply by the abnormal bone. The decrease in vascularity, however, could be due purely to the cytotoxic effect of beryllium.

Osteogenic sarcoma made its appearance thirty to fifty-two weeks after the last injection of beryllium. The morphological appearance of this phase is commented on, particularly the differences between the timorous bone and the abnormal medullary bone of beryllium poisoning and the similarity between this tumor and human osteogenic sarcoma.

NOTE: The authors wish to express their appreciation to Glenn Christensen for his assistance in this study.

## REFERENCES


1. ALDRIDGE, W. N.; BARNES, J. M.; and DENZ, F. A.: Experimental Beryllium Poisoning. British J. Exper. Pathol., **30:** 375–389, 1949.
2. ALLEN, R.; BRONNOR, G.; SPARKS, A.; NEUMAN, W.; SCOTT, J.; and KOSEL, G.: Quoted by Sachs, F. L., and Ballentine, K. D.
3. ARAKI, MASAYA; SANYA, OKADA; and FUJITA, MIKIO: Experimental Studies on Beryllium-Induced Malignant Tumors of Rabbits. Gann (Japanese Journal of Cancer Research), **45:** 449–451, 1954.
4. BARNES, J. M.: Experimental Production of Malignant Tumours by Beryllium [Letter to the Editor]. Lancet, **1:** 463, 1950.
5. BARNES, J. M.; BENZ, F. A.; and SISSONS, H. A.: Beryllium Bone Sarcomata In Rabbits. British J. Cancer, **4:** 212–222, 1950.
6. BROOKES, M., and HARRISON, R. G.: The Vascularization of the Rabbit Femur and Tibio-fibula. J. Anat., **91:** 61–72, 1957.
7. CHEVREMONT, M., and FIRKET, H.: Action of Beryllium on Cells Cultivated In Vitro: Effect on Mitosis. Nature, **167:** 772, 1951.
8. CLOUDMAN, A. M.; VINNING, DOROTHY; BARKULIS, S.; and NICKSON, J. J.: Bone Changes Observed Following Intravenous Injections of Beryllium. *In* Scientific Proceedings. The American Association of Pathologists and Bacteriologists. Am. J. Pathol., **25:** 810, 1949.
9. DOWNS, W. L.: The Effects of Parathyroid Extract on the Bone Lesion Induced by Beryllium Compounds. Contract No. W-7401-eng-49, Rochester, New York, University of Rochester Atomic Energy Project UR-271. Sept. 11, 1953, pp. 1–57.
10. DUTRA, F. R., and LARGENT, E. J.: Osteosarcoma Induced by Beryllium Oxide. Am. J. Pathol., **26:** 197–209, 1950.
11. DUTRA, F. R.; LARGENT, E. J.; and ROTH, J. L.: Osteogenic Sarcoma after Inhalation of Beryllium Oxide. A.M.A. Arch. Pathol., **51:** 473–479, 1951.
12. FROST, H. M.: Preparation of Thin Undecalcified Bone Sections by Rapid Manual Method. Stain Technol., **33:** 273–277, 1958.
13. GARDNER, L. U., and HESLINGTON, H. F.: Osteo-sarcoma from Intravenous Beryllium Compounds in Rabbits. Fed. Proc., **5:** 221, 1946.
14. HALIBURTON, R. A.; SULLIVAN, C. R.; KELLY, P. J.; and PETERSON, L. F. A.: The Extra-osseous and Intra-osseous Blood Supply of the Talus. J. Bone and Joint Surg., **40-A:** 1115–1120, Oct. 1958.
15. HIGGINS, G. M.; HERRICK, J. F.; and JANES, J. M.: The Reaction within the Spleens of Rabbits to Zinc Beryllium Silicate. Reticulo-Endothelial Soc. Bull., **1:** 1–5, 1955.
16. HOAGLAND, M. B.; GRIER, R. S.; and HOOD, M. B.: Beryllium and Growth. I. Beryllium-Induced Osteogenic Sarcomata. Cancer Res., **10:** 629–635, 1950.
17. HOLBERT, J. A.; KELLY, P. J.; PETERSON, L. F. A.; and DAHLIN, D. C.: Osteogenic Sarcoma. A Study Using Microradiography and Histologic Methods. Arch. Pathol., **71:** 20–27, 1961.
18. HUTCHINSON, E. D.; ARMSTRONG, R. D.; MAYNARD, E. A.; and HODGE, H. C.: Toxicology of Beryllium: A Bibliography. Contract No. W-7401-eng-49, Rochester, New York, University of Rochester Atomic Energy Project UR-570. March 5, 1960, pp. 1–74.
19. JANES, J. M.; DAHLIN, D. C.; HERRICK, J. F.; and HIGGINS, G. M.: The Effect of Ultrasonic Energy on Osteogenic Sarcoma: An Experimental Study. Arch. Phys. Med., **38:** 148–156, 1957.
20. JANES, J. M.; HERRICK, J. F.; and HIGGINS, G. M.: The Influence of Splenectomy on the Induction of Osteogenic Sarcoma in Rabbits (Subsequent Report). Proc. Staff Meet. Mayo Clin., **34:** 47–49, 1959.
21. JANES, J. M.; HIGGINS, G. M.; and HERRICK, J. F.: Beryllium-Induced Osteogenic Sarcoma in Rabbits. J. Bone and Joint Surg., **36-B:** 543–552, Nov. 1954.
22. JANES, J. M.; HIGGINS, G. M.; and HERRICK, J. F.: The Influence of Splenectomy on the Induction of Osteogenic Sarcoma in Rabbits. J. Bone and Joint Surg., **38-A:** 809–816, July 1956.
23. JEE, W. S. S., and ARNOLD, J. S.: Structural Changes in Dog Skeleton Containing Plutonium. *In* Proceedings of The Orthopaedic Research Society. J. Bone and Joint Surg., **41-A:** 771, June 1959.
24. JOWSEY, JENIFER: Age Changes in Human Bone. Clin. Orthop., **17:** 210–217, 1960.
25. KELLY, P. J.; PETERSON, L. F. A.; and JANES, J. M.: Ultrastructure of Bone: Technic of

Microradiography and Its Possible Application to the Study of Bone. Proc. Staff Meet. Mayo Clin., **32**: 687–690, 1957.

26. Kelly, P. J.; Peterson, L. F. A.; and Janes, J. M.: A Method of Using Sections of Bone Prepared for Microangiography for Subsequent Histologic Study. Proc. Staff Meet. Mayo Clin., **34**: 274–283, 1959.
27. Looney, W. B.: Late Effects (Twenty-five to Forty Years) of the Early Medical and Industrial Use of Radio-Active Materials. Their Relationship to the More Accurate Establishment of Maximum Permissible Amounts of Radio-Active Elements in the Body. J. Bone and Joint Surg., **37-A**: 1169–1187, Dec. 1955.
28. Morgan, J. D.: Blood Supply of Growing Rabbit's Tibia. J. Bone and Joint Surg., **41-B**: 185–203, Feb. 1959.
29. Nash, P.: Experimental Production of Malignant Tumours by Beryllium. Lancet, **1**: 519, 1950.
30. Oxteux, R.: Les tumeurs expérimentales induites par le beryllium. Cancérologie, **1**:128–130, 1953.
31. Rowland, R. E.; Marshall, J. H.; and Jowsey, J.: Radium in Human Bone: The Microradiographic Appearance. Radiation Res., **10**: 323–334, 1959.
32. Sachs, F. L., and Ballentine, K. D.: Beryllium Toxicology: A Literature Search. Contract No. W-7405-eng-26, Oak Ridge, Tennessee, U. S. Atomic Energy Commission. Carbide and Carbon Chemical Company, Index No. Y-975, July 17, 1953, pp. 1–111.
33. Scott, J. K.: Pathology of Acute Experimental Beryllium Poisoning: Changes Resulting in Venous Blood From Intravenous Administration of Beryllium Sulfate. *In* Pneumoconiosis: Beryllium, Bauxite Fumes, Compensation, pp. 262–282. By A. J. Vorwald, Manfred Bowditch, T. M. Durkan, and T. C. Waters (Ed.). New York, Paul B. Hoeber, Inc., 1950.
34. Scott, J. K.; Neuman, W. F.; and Allen, Roberta: The Effect of Added Carrier on the Distribution and Excretion of Soluble $Be^7$. J. Biol. Chem., **182**: 291–298, 1950.
35. Spalteholz, K. W.: Ueber das Durchsichtigmachen von menschlichen und tierischen Praparaten; nebst AnHang: Ueber Knochenfärbung. Leipzig, S. Hirzel, 1911.
36. Vorwald, A. J.: Personal communication to J. F. Herrick.
37. Vorwald, A. J., and Reeves, A. L.: Inhaled Atmospheric Pollutants in the Genesis of Lung Cancer: An Experimental Study of Biochemical Changes Induced by Beryllium. Acta Union Internationale Contre le Cancer, **15**: 715–722, 1959.
38. Wentz, F. M.; Schour, I.; and Weinmann, J. P.: The Effect of Vitamin D on the Beryllium Rickets of the Rat Incisor. Oral Surg., **11**: 1284–1315, 1958.

# Radical Exarticulation of the Extremities for the Curative and Palliative Treatment of Malignant Neoplasms*

BY ROBERT W. BAILEY, M.D., AND DAVID B. STEVENS, M.D., ANN ARBOR, MICHIGAN

*From the Department of Surgery, Section of Orthopaedic Surgery, University of Michigan Medical Center, Ann Arbor*

This study was undertaken to determine the palliative or curative results of radical ablation of extremities with malignant tumors. Few reports of large series of this kind exist [2,3,4,6,7]; especially lacking are reports with long-term follow-ups and end results. An appraisal of the results with this form of treatment seemed timely because of the advent of isolation-perfusion techniques employing tumoricidal drugs. The work of Creech and his associates indicated inconsistent palliative effects with this technique for most sarcomata, with no definite cures. In fibrosarcomata, some of the strikingly favorable responses reported by Creech and associates were followed by recurrence of symptoms, and, in one patient, an osteogenic sarcoma progressed rather than regressed after perfusion.

The cases reported here represent all the patients treated by exarticulation at the University of Michigan Medical Center and its allied orthopaedic services between 1945 and 1959. In the majority of this group of patients, amputation was performed in the hope of obtaining a cure. In two instances amputation was done because of a secondary metastatic lesion in the extremity in order to relieve pain and eliminate a tumor which showed evidence of ultimate breakdown of overlying tissue and a fungating, painful mass. The only alternative might have been a chordotomy or some other neurosurgical procedure to relieve pain. Not included are those patients in whom the location and extent of the tumor permitted treatment by more conservative amputation or by block resection. In several patients in this series, block resection of the tumor was considered before amputation, but at operation, it was found that block resection could not be accomplished either because it would sacrifice function of the extremity or would result in incomplete removal of the tumor. Exarticulation in these patients was considered the only possible treatment.

The anatomical location of the tumors in this group did not allow complete removal of the tumor by block resection or by amputation at lower levels. Whenever feasible, excisional biopsies were performed. During the period of the study a number of patients with sarcomata of the extremity had excisional biopsies and have not come to any form of amputation. Three block resections performed during this time for lesions involving the pelvic or pectoral girdle are noteworthy. They are summarized here to stress that, when feasible, block resection of lesions in the region of the pectoral or pelvic girdle can be carried out with hope of cure and preservation of a functional extremity.

CASE A. In 1953, a white woman, fifty-two years old, had a block resection of the proximal five inches of the right humerus for enchondroma, which showed chondrosarcomatous degeneration but did not appear to have invaded the soft tissues adjacent to the bone. The upper seven inches

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Miami Beach, Florida, January 12, 1961.

TABLE I

HEMIPELVECTOMY
(Sixteen Patients)

| Patient | Age (*Years*) | Diagnosis | Date of Operation | Date of Death* |
|---|---|---|---|---|
| E.W. | 44 | Chondrosarcoma of the ilium | 3/48 | |
| L.W. | 33 | Osteochondroma of the ilium with osteogenic sarcomatous changes | 4/49 | |
| L.T. | 56 | Carcinoma of the lung with metastases to upper part of the femur | 12/49 | 5/50 |
| B.D. | 65 | Fibrosarcoma of the upper part of the thigh | 5/50** | 5/50 |
| C.M. | 48 | Chondrosarcoma of the ilium | 4/45 | 1/54 |
| W.H. | 61 | Fibrosarcoma of the upper part of the thigh involving Scarpa's triangle† | 12/52** | 2/53 |
| H.R. | 49 | Fibrosarcoma of the upper part of the thigh involving Scarpa's triangle | 11/53 | 6/54 |
| W.B. | 66 | Osteogenic sarcoma of the left hip in an area of Paget's disease | 12/53 | |
| C.C. | 33 | Chondrosarcoma of the ilium | 4/54 | 4/54 |
| M.K. | 37 | Osteogenic sarcoma of the ilium | 6/54 | 10/55 |
| L.R. | 43 | Chondrosarcoma of the ilium | 9/54 | 11/57 |
| F.W. | 44 | Chondrosarcoma of the ilium | 11/56 | 3/57 |
| R.D. | 58 | Chondrosarcoma of the ilium | 11/56 | |
| F.H. | 48 | Osteogenic sarcoma of the right pelvis (? secondary to irradiation)† | 5/59** | |
| W.H. | 57 | Fibrosarcoma of the upper part of the thigh encroaching on Scarpa's triangle | 5/59 | 10/59 |
| S.D. | 14 | Osteogenic sarcoma of the femoral neck | 6/59 | |

* Where no date is mentioned, the patient is alive at the time of writing.
** Complete removal of the tumor was not possible.
† Pulmonary metastases was known at operation.

of the left fibula was transplanted into the defect. At the time of writing, this woman is alive and completely free from tumor. Despite pseudarthrosis at the junction of the fibular graft with the humerus, the remainder of the extremity is normal and the hand is used in a normal way.

CASE B. In July 1959, a twenty-nine-year-old white woman had the left pubis and inferior ramus of the ischium excised *en bloc* for osteochondroma of the inferior ramus of the pubis which had undergone chondrosarcomatous change. At the time of writing she is well with no evidence of recurrence or metastasis.

CASE C. In 1953, a twenty-nine-year-old white woman was treated for chondroblastoma with fibrosarcomatous change in the proximal portion of the right humerus. Although forequarter amputation was advised, this was refused by the patient. Accordingly, the proximal portion of the humerus was excised and a portion of the fibula transplanted into the defect. The patient did poorly after operation and died within one year with pulmonary metastases.

## MATERIAL

In the thirty-four patients in this series hemipelvectomy was done in sixteen, disarticulation of the hip in ten, and forequarter amputation in eight. Twenty of these procedures were performed from 1945 to 1956, and fourteen from 1956 to 1959 (Tables I, II, and III). In two patients hemipelvectomies were performed for metastatic lesions. One with a metastatic carcinoma of the lung in the upper part of the femur died four months after operation; the other, with a metastatic hypernephroma in the upper one-third of the femur also died five months after operation. In each instance, there was extensive destruction of the femur, a pathological fracture, and large tumor in the proximal portion of the thigh.

The remaining thirty-two patients were treated for primary neoplasms of the extremity. Of the fifteen treated by hemipelvectomy, six are still alive eighteen

TABLE II

HIP DISARTICULATION
(Ten Patients)

| Patient | Age (*Years*) | Diagnosis | Date of Operation | Date of Death* |
|---|---|---|---|---|
| E.S. | 54 | Fibrosarcoma of the middle one-third of the thigh | 12/47 | 9/51 |
| S.T. | 28 | Fibrosarcoma of the proximal lateral portion of the thigh | 3/51 | |
| S.W. | 40 | Squamous-cell carcinoma of the skin of the proximal portion of the thigh | 10/51 | 6/52 |
| M.B. | 49 | Fibrosarcoma of the middle one-third of the thigh | 7/54 | 7/56 |
| A.S. | 51 | Fibrosarcoma of the middle one-third of the thigh | 3/55 | 5/55 |
| T.P. | 8 | Fibrosarcoma of the middle one-third of the thigh | 11/56 | 2/57 |
| Z.D. | 19 | Osteogenic sarcoma of the distal portion of the femur | 4/57 | 2/59 |
| P.R. | 47 | Rhabdomyosarcoma of the middle one-third of the thigh | 8/57 | 12/59** |
| A.F. | 36 | Fibrosarcoma of the middle one-third of the thigh | 10/58 | |
| C.V. | 69 | Metastatic hypernephroma of the upper third of the femoral shaft | 3/59 | 8/59 |

* Where no date is mentioned, the patient is alive at the time of writing.
** Death caused by hypertension.

TABLE III

FOREQUARTER AMPUTATION
(Eight Patients)

| Patient | Age (*Years*) | Diagnosis | Date of Operation | Date of Death* |
|---|---|---|---|---|
| B.B. | 12 | Chondrosarcoma of the scapula | 3/46 | |
| L.P. | 68 | Chondrosarcoma of the scapula | 5/49 | |
| A.J. | 12 | Chondroblastoma of the proximal part of the humerus with fibrosarcomatous change | 5/50 | 1/51 |
| M.M. | 17 | Fibrosarcoma of the upper one-third of the arm | 11/50 | |
| D.S. | 23 | Osteogenic sarcoma of the scapula | 8/56 | 11/57 |
| F.O. | 26 | Hemangio-endothelioma of the scapula | 6/57 | |
| B.G. | 29 | Fibrosarcoma of the upper part of the arm | 1/58 | |
| A.B. | 54 | Leiomyosarcoma of the upper part of the arm | 5/58 | |

* Where no date is mentioned, the patient is alive at the time of writing.

months to thirteen years after operation. Of the nine patients who had disarticulation of the hip for primary neoplasm, two are alive twenty-six months and ten years, respectively, after operation. Six of the eight who had forequarter amputations are alive at from two and one-half to nearly fifteen years after operation. Thus, of the whole group 43.8 per cent of the patients are still alive eighteen months or more after operation, and of the nineteen operated on for primary neoplasms between 1945 and 1956, seven are alive and well, giving a five-year survival rate of 36.8 per cent. The average time of survival after operation of the patients who died was twelve months.

Surgical procedures of several types had been performed on many of these patients prior to exarticulation. It was of interest that four patients with fibrosarcoma in the thigh apparently had been initially suspected of having an abscess of the thigh for which aspiration or incision had been done as a primary surgical procedure. In more than half of the patients with lesions of the lower extremities, previous attempts at local excision had been unsuccessful; in four patients, more than one attempt at block excision had failed. Two of these patients had fibrosarcomata of the thigh; one, rhabdomyosarcoma of the thigh; and the other, chondrosarcoma of the ilium. In three of the eight patients who had forequarter amputations, local excision on at least one occasion had failed to cure, respectively, hemangio-endothelioma, fibrosarcoma, and leiomyosarcoma of the posterior scapular area.

## RELATIONSHIP BETWEEN DIAGNOSIS AND SURVIVAL

There were twelve patients treated for fibrosarcomata: four by hemipelvectomy, six by hip disarticulation, and two by forequarter amputation. Four of these patients are alive at the time of writing. One is well two years after hip disarticulation for a lesion in the thigh. Another is well three years after forequarter amputation for a lesion in the upper third of the humerus. The third patient is living ten years after forequarter amputation for fibrosarcoma involving the region of the insertion of the pectoralis major. For nine years after operation, he was without evidence of metastases; recently, however, a pea-sized lesion appeared in the fascia of the medial aspect of the middle third of the left arm which, when removed, was found to be histologically identical to the original tumor. The fourth survivor had hip disarticulation for fibrosarcoma in the proximal portion of the thigh. He is alive and well two and one-half years after operation.

Nine patients had chondrosarcomata: six were treated by hemipelvectomy and three by forequarter amputation. After hemipelvectomy, two with lesions of the ilium are alive four and twelve years after operation, respectively. One of the others survived nine years after forequarter amputation for a lesion of the scapula and then died with metastases. Of the patients treated by forequarter amputation, two are alive roughly fourteen and eleven years after operation. The other died seven months after surgery.

There were seven patients with osteogenic sarcomata: five were treated by hemipelvectomy, one by hip disarticulation, and one by forequarter amputation. Two are alive and have survived more than five years. One had a hemipelvectomy for chondroma of the ilium with early osteochondrosarcomatous change; the other, a hemipelvectomy for osteogenic sarcoma in an area of Paget's disease in the proximal portion of the femur. Since this case appears to be one of the longest recorded survivals of a patient with sarcomatous degeneration in Paget's disease, it seems worth reporting.

## CASE REPORTS

W.B., a farmer, sixty-six years old, came to the University Hospital in July 1953, with a pathological intertrochanteric fracture of the left femur secondary to Paget's disease of the femur and pelvis (Fig. 1-A). He was treated by traction for four months without roentgenographic evidence of healing. The upper part of the thigh progressively increased in circumference and roentgenograms revealed extensive irregular ossification in the soft tissues (Fig. 1-B). Biopsy showed Paget's disease and osteogenic sarcoma. On December 17, 1953, a hemipelvectomy was done, and, in order to remove the tumor completely, anteriorly, the left testicle and vas deferens were also removed (Fig. 1-C). Three months later, roentgenograms of the chest revealed several large soft-tissue densities in both lung fields which were interpreted as metastases (Fig. 1-D). These densities have not changed appreciably in seven years and the patient has remained free of pulmonary symptoms.

FIG. 1-A

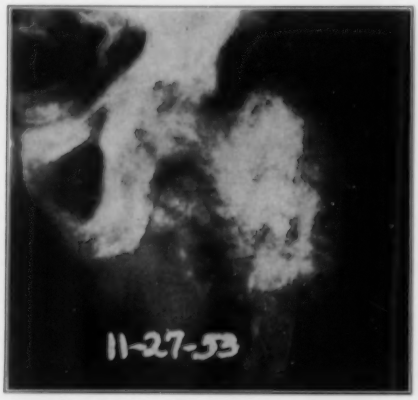



FIG. 1-B

Fig. 1-A: W.B., a man, sixty-six years old, fell in a bathtub on July 19, 1953. Roentgenograms made the following day revealed a comminuted intertrochanteric and subtrochanteric fracture of the left femur in an area of Pagets disease, which also involved the greater part of the left hemipelvis.

Fig. 1-B: The fracture was treated in modified Russell skeletal traction. During the next three months, massive swelling gradually developed in the left thigh and a bruit and palpable thrill appeared over Scarpa's triangle. A roentgenogram made on November 11, 1953, showed extensive soft-tissue ossification, which suggested osteogenic sarcomatous degeneration; this was confirmed by biopsy.

FIG. 1-C

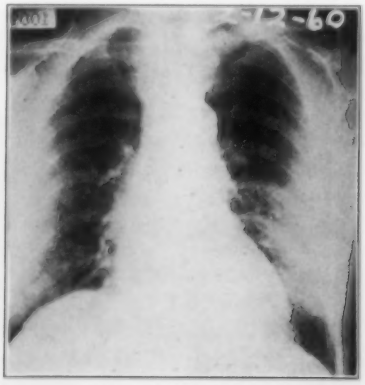


FIG. 1-D

Fig. 1-C: Hemipelvectomy was performed in December 1953, and recovery was uneventful. No tumor was apparent on this roentgenogram, made four years after operation. In 1959, the patient was operated on for a suspected bleeding duodenal ulcer. A metastatic osteogenic sarcoma was found entirely replacing a segment of the jejunum

Fig. 1-D: Roentgenogram made on February 12, 1960, shows no appreciable change from that made in 1954, three months after hemipelvectomy, in which nodular lesions appeared in both lung fields.

In December 1958, incidental to laparotomy for duodenal ulcer, a metastatic osteogenic sarcoma was found constricting the jejunum, twelve inches distal to the ligament of Treitz. This area was resected and, on histological examination, showed osteogenic sarcoma. The patient is asymptomatic at the time of writing.

Another case worthy of note is that of F.H., a forty-eight-year-old woman with hip pain for one year and evidence, on roentgenograms, of osteogenic sarcoma of the pelvis (Fig. 2-A). Twenty-six years earlier, she had had radium and roentgen therapy for carcinoma of the uterine cervix. A hemipelvectomy was done and a huge osteogenic sarcoma was incompletely removed because the tumor had extended along the iliopsoas muscle (Fig. 2-B). Three months after operation pul-

FIG. 2-A

F.H., a woman, forty-eight years old, was referred to us in April 1959, with osteogenic sarcoma of the right pelvis. A roentgenogram was made on April 30, shortly after admission. Twenty-six years previously, she had been treated with radium and roentgen therapy for carcinoma of the uterine cervix. Biopsy confirmed the suspicion of osteogenic sarcoma.

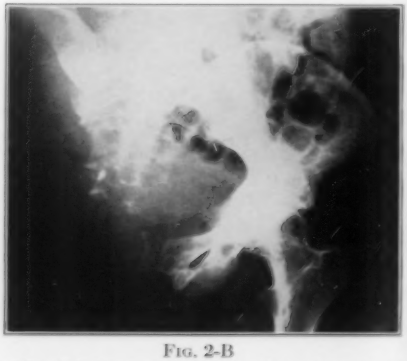


FIG. 2-B

FIG. 2-C

Fig. 2-B: Roentgenogram made on May 25, 1959, one month after hemipelvectomy. The tumor was incompletely removed at amputation because of the extensive invasion of the iliopsoas. Note the persistence of tumor bone in the soft tissue.

Fig. 2-C: Roentgenogram made on August 25, 1959, four months after operation. There is further proliferation of tumor bone in the soft tissues. Roentgenograms of the chest, made at the same time, revealed definite metastatic lesions.

monary metastases appeared (Fig. 2-C); however, this patient is still alive twenty months after operation.

The survival data for the remaining patients treated by exarticulation for primary tumors of the extremities are as follows: Two patients, one with hemangio-endothelioma and the other with leiomyosarcoma, are living and

clinically free of tumor, three and two years, respectively, after operation. A patient with squamous-cell carcinoma of the upper part of the thigh died of metastases within a year following operation. A patient with rhabdomyosarcoma of the thigh died of cerebral hemorrhage two years after exarticulation, but no residual tumor was found at autopsy.

### OPERATIVE MORBIDITY AND MORTALITY

With improved surgical techniques, modern anesthesia, blood transfusion, and antibiotic therapy, the morbidity and mortality after radical surgery has steadily decreased. The simplified technique for hemipelvectomy, as described by King and Steelquist, has also been a worth-while contribution.

In two patients who underwent hemipelvectomy, it was necessary to remove the testicle and vas deferens in order to excise the tumor completely. Because of the proximity of the rectal orifice to the line of resection, our present routine includes preoperative enemas and preoperative antibiotic therapy with neomycin. Wound dehiscence occurred in two patients who underwent hemipelvectomy, and in a third there was serous drainage from the incision for one month. No difficulty was encountered with wound healing following hip disarticulation or forequarter amputation.

There were no true operative deaths in this series, but one patient died on the first day after hemipelvectomy for a tumor of the ilium weighing twenty pounds. The exact cause of death was not clear, but it seemed to be of respiratory origin. A second patient died three months after hemipelvectomy as a result of septicemia secondary to postoperative wound infection.

### GENERAL OBSERVATIONS

In this series, hip disarticulation was performed for lesions in the upper portion of the thigh, whereas hemipelvectomy was performed largely for tumors that involved the pelvic girdle. However, hemipelvectomy was also employed in fibrosarcomatous lesions that were situated close to the inguinal ligament in Scarpa's triangle. Before operation, it is frequently difficult to determine the extent of soft-tissue involvement by tumor. In two fibrosarcomata situated high in Scarpa's triangle and extending along the iliac fossa, it was recognized that the tumor had not been completely removed by hemipelvectomy. One patient survived less than one month following operation, death being due to pulmonary metastases. The second patient survived four months but was given complete relief from pain resulting from a huge tumor.

In a third patient in whom hemipelvectomy was performed for osteogenic sarcoma of the pelvis (Case F.H.), it was only after the external iliac artery and vein had been ligated and the surgeon committed to removal of the limb that it was discovered on transecting the ilium that the tumor extended above the level of amputation. Relief from pain was obtained. At the time of writing, the patient is alive and relatively well.

The procedure in two cases with incomplete removal of the tumor was of value since the alternative procedure would have been chordotomy. In the third patient who died within the first postoperative month, one would question the value of the surgical procedure.

The high incidence of survival after forequarter amputation, compared with the survival of patients undergoing exarticulation of the lower extremity, is noteworthy. It is not possible to relate this difference in survival time in this small series to the histological characteristics of the lesions since the tumors of both groups were histologically similar. We believe that the difference in results may

be related to the anatomical characteristics of the upper and lower extremities and the pelvic and pectoral girdles. Perhaps, the independence of the shoulder girdle from the trunk, as compared with the pelvic girdle, allows wider resection of tumors in that area. For example, when a chondrosarcoma occurs on the anterior aspect of the scapula, the lesion is separated from the trunk not only by the muscles arising from the scapula but also by the serratus anticus. There is no such anatomical separation of tumors in the pelvic girdle from the viscera in that area. This explanation may account for the survival of two patients with chondrosarcomata of the scapula for eleven and fourteen years, respectively, after exarticulation, whereas equal success has not been experienced in patients undergoing hemipelvectomy for chondrosarcoma of the pelvis.

It is of further interest to note that shoulder disarticulation has not been performed for tumors of the upper extremity at the University of Michigan Medical Center from 1946 to 1959. We believe there are distinct advantages of forequarter amputation over shoulder disarticulation, as reported by Pack: (1) forequarter amputation removes the lymphatics and veins at a higher level, (2) the shoulder muscles and their natural fascial planes are entirely removed by forequarter amputation, and (3) forequarter amputation eliminates the major portion of the axilla. Moreover, removal of the scapula, although leading to a more significant deformity, eliminates any dead space and encourages rapid wound healing. In the eight forequarter amputations recorded in this series, no difficulties were experienced in wound healing.

It should be emphasized that forequarter amputation is not indicated if the tumor is anatomically situated so that an amputation of a lesser degree would result in complete removal of the tumor. However, when the axilla or pectoral girdle is involved by a tumor of the types discussed, we advise forequarter amputation.

The results of attempting to fit patients who had had major exarticulations of the extremities with prosthetic devices have, in general, been disappointing. Most of the patients have not worn a prosthesis although, in each instance, it was offered. The patients with forequarter amputations have used simple prosthetic devices, such as an arm pad or shoulder pad. None has used a functional prosthesis. Despite attempts to fit a number of patients with prostheses after hemipelvectomy or disarticulation of the hip, only two recent patients were fitted successfully with Canadian hip-disarticulation prostheses: one after disarticulation of the hip, and the other, after hemipelvectomy.

## SUMMARY

From 1945 to 1959, thirty-four patients with malignant tumor of the extremities were treated by exarticulation at the University of Michigan Medical Center. Two of these patients were so treated to palliate painful metastatic lesions. In three others, all of whom were treated by hemipelvectomy, incomplete removal of the tumor at the time of surgery was recognized. Of the thirty-two patients treated for primary malignant tumors in the extremities, fourteen are still alive. Of ten patients who had disarticulation of the hip, only one has survived longer than five years; another still survives, at the time of writing, two and one-half years after operation. Of the sixteen patients undergoing hemipelvectomy, four have survived more than five years; three more, who were operated on less than five years ago, are alive at the time of writing. Of eight patients who had forequarter amputation, three have survived longer than five years, and three more are still alive less than five years after operation.

REFERENCES

1. Creech, Oscar, Jr.; Krementz, E.T.; Ryan, R.F.; Reemtsma, Keith; and Winblad, J.N.: Experiences with Isolation-Perfusion Technics in the Treatment of Cancer. Ann. Surg., **149:** 627–640, 1959.
2. Dahlin, D.C., and Henderson, E.D.: Chondrosarcoma. A Surgical and Pathological Program. Review of 212 Cases. J. Bone and Joint Surg., **38-A:** 1025–1038, Oct. 1956.
3. Gordon-Taylor, Gordon; Wiles, Philip; Patey, D.H.; Warwick, W.T.; and Monro, R.S.: The Interinnomino-Abdominal Operation. Observations on a Series of Fifty Cases. J. Bone and Joint Surg., **34-B:** 14–21, Feb. 1952.
4. Higinbotham, N.L., and Coley, B.L.: Hemipelvectomy: Experience in a Series of Thirty-nine Cases. Cancer, **9:** 1233–1238, 1956.
5. King, Don, and Steelquist, John: Trans-Iliac Amputation. J. Bone and Joint Surg., **25:** 351–367, Apr. 1943.
6. Lewis, R.C., Jr., and Bickel, W.H.: Hemipelvectomy for Malignant Disease. J. Am. Med. Assn., **165:** 8–12, 1957.
7. Pack, G. T.: Major Exarticulations for Malignant Neoplasms of the Extremities: Interscapulothoracic Amputation, Hip-Joint Disarticulation, and Interilio-Abdominal Amputation. A Report of End Results in 228 Cases. J. Bone and Joint Surg., **38-A:** 249–262, Apr. 1956.

## DISCUSSION

Dr. J. Leonard Goldner, Durham, North Carolina: Dr. Bailey and Dr. Stevens have given us the information concerned with amputation for malignant tumors during a fifteen-year period at the University of Michigan Medical Center. They emphasized several problems for which solutions can only come from studies similar to this one in many areas of the country. I shall mention a few of these problems.

1. Diagnosis of a malignant tumor demands close cooperation between the surgeon, roentgenologist, and frequently more than one pathologist, all of whom have been given the benefit of history, roentgenograms, and adequate tissue for histological examination. In questionable cases, do not let your ego or that of the pathologist in your locality stop you from seeking outside opinion.

2. The site of amputation will vary depending on the tumor and its usual prognosis. Tumors in a proximal area, such as the upper part of the thigh and arm usually demand forequarter and hindquarter amputation, although there may be exceptions to this rule. Block resection of chondrosarcoma appears to be more worth while in the scapula, fibula, or similar areas than in the tibia or femur. The patient with partial resection of the lesion of the pelvis has had a follow-up of only one and one-half years. We should wait until we have more information or a longer follow-up on a localized resection of chondrosarcoma of the pelvis before we arrive at a definite opinion concerning the advisability of limited resection in this area.

3. Perfusion. At the present time, the information available is incomplete. What is the best time to perfuse? How can systemic overflow of a potentially harmful drug be controlled? What is the effect of the drug on the local lymphatics or the distant lymphatics? What is the duration of tissue damage? There are numerous questions which will have to be answered in the future. In our clinic, we have two twelve-year-old patients who have had osteogenic sarcoma. Both had perfusion of nitrogen mustard derivative and, following the perfusion, immediate hip disarticulation within thirty minutes of the perfusion. Both are taking oral cytoxin, which is a nitrogen mustard drug; one has done well now for a year, the other for only two months. Obviously, no conclusion can be drawn from this history, other than to state that these patients tolerated perfusion followed by amputation.

Radioactive tracer techniques indicate that a 30 per cent systemic overflow may occur when a lower extremity is perfused at a high level, even with a tourniquet in place above the insertion of the catheter in the femoral artery. If the patient's bone marrow can tolerate this amount of overflow of the particular drug being used, this systemic overflow may be beneficial. If the diagnosis is reasonably certain clinically and roentgenographically, it might be advisable to perform a biopsy, followed immediately by perfusion to decrease the possibility of systemic tumor emboli. If the biopsy specimen confirms the original diagnosis, then amputation should be carried out as soon as possible. All this, however, is only conjecture; much more experience is needed before any conclusion can be reached.

4. Prosthesis. In our amputee clinic, we have several teen-age patients wearing conventional above-the-knee prostheses after mid-thigh amputation for malignant tumor of the tibia or below. We also have three patients—two women and one man—who are using shoulder-disarticulation prostheses after forequarter amputation; all three have been using their limbs for over a year now and find them to be a distinct advantage. We have three patients wearing Canadian hip prostheses after hip disarticulation or hemipelvectomy; one for three years, one for two years, and one for nine months. They are all good users. Certain patients are not eligible for prostheses; this is an individual selection. It is desirable to wait about one year after operation for the patient's weight to stabilize, the stump to shrink, and the progress of the tumor to be ascertained before deciding

whether the patient should be fitted. If the patient desires it, and he seems to be a good candidate, he certainly should be given that privilege.

5. When to do more surgery after the original amputation? At present, we are following a forty-three-year-old woman who had hip disarticulation five years ago for proved fibrosarcoma of the lower part of the femur. A Canadian type hip-disarticulation prosthesis was prescribed one year after operation.

Four years ago, she had a partial lobectomy for isolated pulmonary metastasis, the same tumor being found in the lung. She continued wearing her prosthesis. Two years ago, she had a small localized cerebral metastasis removed from the frontal lobe of her brain, which was found to be the same tumor. She is still up, going around now with a mild speech defect, wearing her limb six or seven hours a day, and continues living with real enthusiasm. Should we have stopped at the hip, or the chest, or the head? The answer is obviously no.

6. Chordotomy *versus* hemipelvectomy for osteogenic sarcoma of the pelvis is a difficult decision and certainly requires consideration of all the other aspects of the problem that the authors have mentioned. We have one sixteen-year-old girl, treated fifteen years ago by radiation therapy and radium implants for a Wilms' tumor. In her, too, there developed osteogenic sarcoma of the pelvis involving the iliac crest. Hemipelvectomy was not feasible because of extensive invasion by the tumor. High chordotomy was done with relief of buttock and thigh pain, but discomfort in the pelvis persisted. She died at the age of seventeen from pulmonary metastases.

A few more reviews like this just presented may make the decision concerning chordotomy *versus* radical resection in these selected cases somewhat easier.

DR. BAILEY (closing): I should like to point out that a number of these amputations were done prior to the development of the Canadian hip-disarticulation prosthesis. The tilt table prosthesis, when tried, was of no value.

None of the patients with forequarter amputation wears a functional prosthesis. When initially fitted, I believe the patients worked diligently with the prosthesis, more to please the physician in the Amputee Clinic than for any improvement in function they experienced. The prostheses were subsequently discarded.

Dr. Goldner's points regarding follow-up for evidence of distant metastases is most important. Isolated, single pulmonary metastasis has been removed in a number of instances of bone tumor at the University Hospital with cures resulting. A number of patients were so treated in the past by the late Dr. John Alexander and more recently by Dr. Cameron Haight.

# Some Skeletal Changes in the Ehlers-Danlos Syndrome

## A Report of Two Cases

BY MARK B. COVENTRY, M.D., ROCHESTER, MINNESOTA

*From the Section of Orthopedic Surgery, Mayo Clinic and Mayo Foundation, Rochester*

McKusick recently grouped together certain inherited conditions involving the mesenchyme which he called "heritable disorders of connective tissue". These include the Marfan syndrome, the Ehlers-Danlos syndrome, the Hurler syndrome (gargoylism), osteogenesis imperfecta, and pseudoxanthoma elasticum. He suggested that several other heritable disorders, such as Paget's disease of bone, may be due primarily to connective-tissue abnormalities.

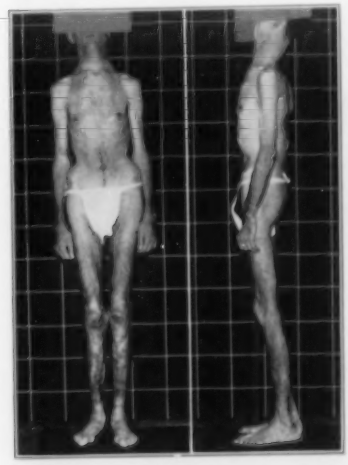


FIG. 1-A

Case 1. Appearance of the patient.

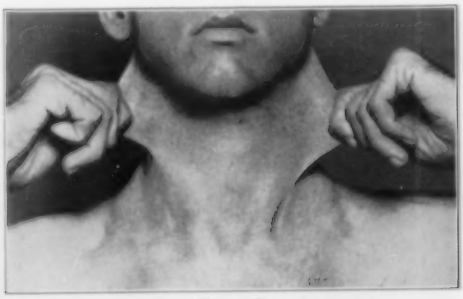


FIG. 1-B

Hyperelasticity of the skin.

According to McKusick, the Ehlers-Danlos syndrome was first described in 1682 by Job van Meekeren as a condition characterized by tremendously loose, hyperelastic skin. It was further defined by Ehlers in 1901 and Danlos in 1908: Ehlers described the loose-jointedness and subcutaneous hemorrhages and Danlos the tumors in the skin and subcutaneous tissue which he termed *molluscoid pseudotumors*.

In this syndrome, then, the skin is velvety, thin, hyperelastic, but not lax; it is brittle, fragile, bruises easily, and leaves scarring after subcutaneous hemorrhage. Molluscoid fibrous tumors develop over pressure points at the elbows and knees; these tumors may calcify. The skin of the pretibial areas is thin, scarred, and pigmented; the joints are hypermobile—so-called double-jointedness.

Patients with this syndrome are the contortionists and India-rubber men of the circus side show. Elbows and knees hyperextend, the thumb can be brought back to touch the forearm, and the arms can be twisted above the head in grotesque fashion. Flat feet, habitual dislocation of joints, and kyphoscoliosis are often observed.

The Ehlers-Danos syndrome is also characterized by changes in the eye which occur in the ocular adnexa, the cornea, the sclera, the suspensory

FIG. 1-C

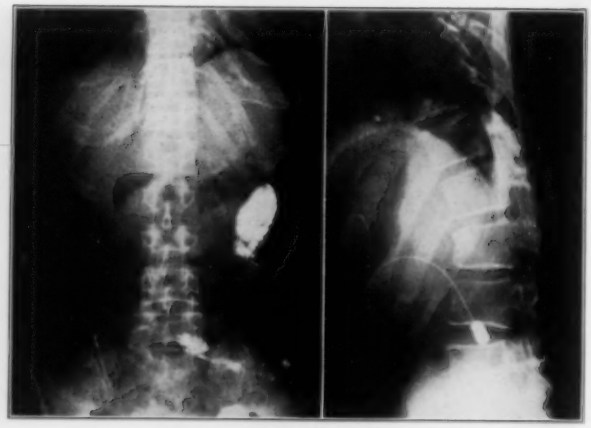


FIG. 1-D

Fig. 1-C: Soft-tissue changes in the shin areas: note the thin, pigmented skin and the pseudotumor in the region of the left ankle.

Fig. 1-D: Anteroposterior and lateral roentgenograms of the lumbar spine show anterior wedging of the twelfth thoracic vertebra.

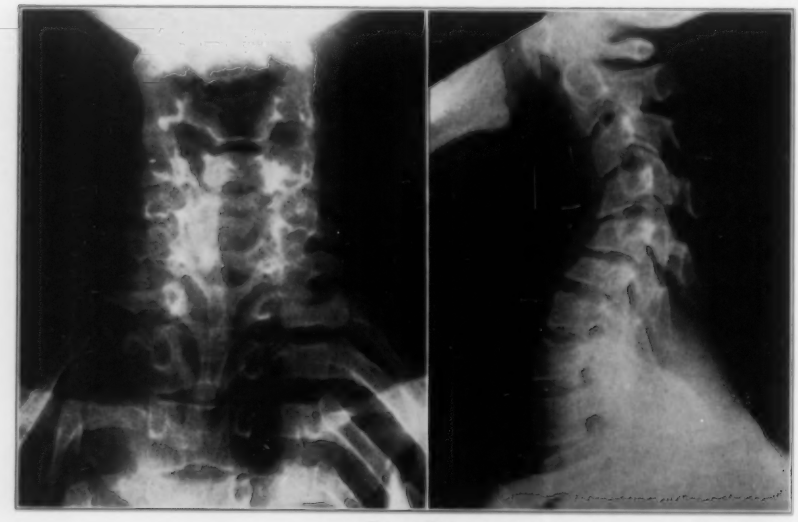


FIG. 1-E

Anteroposterior and lateral roentgenograms of the cervical spine: note the reversal of the upper portion of the cervical curve, which presents a kyphotic appearance and allows visibility of all cervical and upper thoracic vertebrae.

mechanism of the lens, and the fundus. Ectopia lentis is not constant, as it is in the Marfan syndrome. The skin above the eyes may be redundant, and the sclera is often blue. Visceral structures may be involved as well, resulting in, for example, diaphragmatic hernia, ectasia of the alimentary and respiratory tracts, and dissecting aneurysm of the aorta.

There is no constant tendency to abnormally long extremities in this syndrome, as there is in the Marfan syndrome; most patients are tall, but some are short.

FIG. 1-F

FIG. 1-G

Fig. 1-F: Anteroposterior roentgenogram of the chest: note the extreme downward sloping of the ribs, with narrowing of the thoracic cage.

Fig. 1-G: Lateral roentgenogram of the thoracic spine shows reversal of the usual kyphosis in this region.

The basic mesenchymal defect in the Ehlers-Danlos syndrome is probably a superabundance of elastic fibers in the skin and joint capsules, with an abnormal organization or network pattern of the collagen bundles and perhaps an abnormality in the collagen structure itself [5].

The syndrome has always been described as affecting Europeans (Caucasians), whereas many of the other heritable connective-tissue disorders are found in the Negro and Oriental races, as well as in the Caucasian. Recently, however, Ehlers-Danlos syndrome has been found in the Negro, four members in two generations of the same family being affected [1].

There is confusion in classifying patients with hyperelasticity of the skin and hypermobility of the joints, but without scarred skin over the tibiae and without pseudotumors. This state is probably a manifestation of the Ehlers-Danlos syndrome, but of a different degree.

During the past year, I have observed two adult patients with the Ehlers-Danlos syndrome with skeletal changes of sufficient interest, in my opinion, to warrant publication.

## REPORT OF CASES

CASE 1. A single man, thirty-three years old, an embalmer, was admitted to the gastro-intestinal service of the Mayo Clinic because of recurrent epigastric cramping and vomiting. He gave a history of lifelong trouble with his skin, which was easily cut or bruised and which bled frequently after minor trauma. Frequent bruising eventually resulted in the development of small fluctuant tumors, which often drained thin, bloody fluid. Although the joints of his fingers and toes were hyperextensible, there had been no dislocation of major joints. He was myopic and had loss of subcutaneous fat. He was seventy-eight inches tall, but weighed only 119 pounds (Fig. 1-A).

His skin was smooth and hyperelastic (Fig. 1-B) except over the tibial crests, where it was thin, scarred, and pigmented (Fig. 1-C).

His neck seemed to be abnormally long, and his chest was pointed anteriorly and sloped from the neck down. The upper portion of the cervical curve was reversed and presented a kyphotic

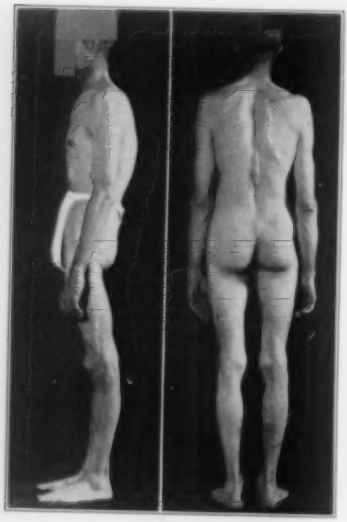


FIG. 2-A

Case 2. The side view shows lower thoracic kyphosis and hyperextended hips; the back view reveals absence of the upper but presence of the lower thoracic kyphosis.

appearance; yet, the lower half of the neck was in the usual lordosis. The thoracic portion of the spinal column lacked the usual kyphosis and was rigidly straight above the level of the ninth and tenth thoracic vertebrae. At the thoracolumbar junction, there was an abnormal posterior curve. In other words, there was a tendency to reversal of the normal spinal curvature.

The feet were not flat, and the elbows did not hyperextend; but the fingers and thumb did to a marked degree.

Laboratory investigation included Vitamin-C level in the blood plasma, serum polysaccharide, and urine polysaccharide. All findings were considered to be within normal limits. One of the pseudotumors over the knee was excised and examined; it showed traces of cholesterol, but otherwise it presented the microscopic picture of fibrosis.

Roentgenograms of the thoracolumbar spine showed kyphosis and anterior vertebral wedging (Fig. 1-D), similar to, but not as marked as, the findings reported by Macfarlane. There was also a kyphosis in the cervical spine (Fig. 1-E). The anteroposterior roentgenogram of the cervical and thoracic spine revealed that the abnormally long appearance of the neck observed clinically was caused by the downward slanting of the shoulders and ribs (Figs. 1-E and 1-F). Of considerable interest also was the fact that the lateral roentgenogram of the cervical spine allowed visualization of not only all the cervical vertebrae but also the first three thoracic vertebrae. This may well be a diagnostic sign of the Ehlers-Danlos syndrome. No previous report of this phenomenon could be found. Of additional interest and also not previously reported was the marked deformity of the thoracic cage, especially the upper portion, which appeared compressed and elongated. The ribs pointed distally and the thorax was funnel shaped, tapering down and out from top to bottom (Fig. 1-F). The thoracic spine was ramrod straight, as seen in Figures 1-A and 1-G. The usual lumbar lordotic curve was almost lacking. The patient had no symptoms referable to the musculoskeletal system.

FIG. 2-B

FIG. 2-C

Fig. 2-B: Double-jointedness with ability to touch the thumb to the forearm.
Fig. 2-C: Hyperelasticity of the skin.

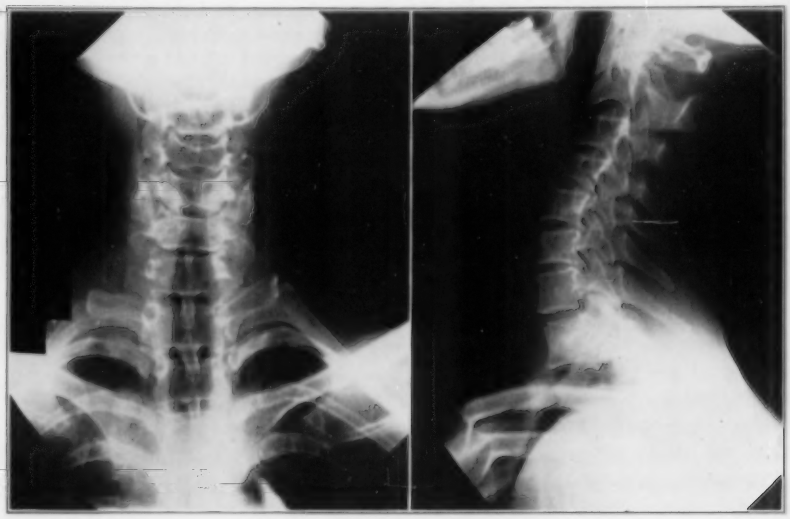


FIG. 2-D

Anteroposterior and lateral roentgenograms of the cervical spine allow visualization of the lower cervical vertebrae and even the upper two or three thoracic vertebrae.

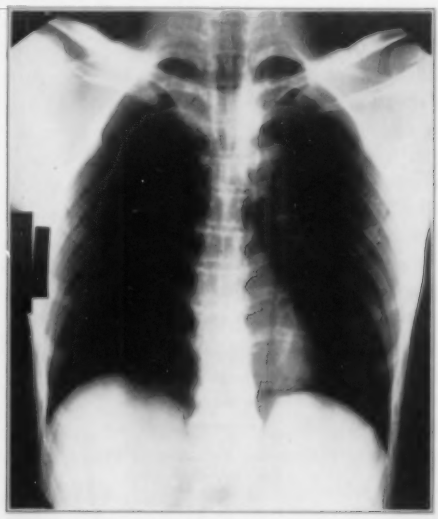


FIG. 2-E

FIG. 2-F

Fig. 2-E: Anteroposterior roentgenogram of the thoracic spine shows the downward slope of the upper ribs.

Fig. 2-F: Lateral roentgenogram of the thoracic and upper part of the lumbar spine shows reversal of the upper thoracic kyphosis and the presence of wedging of the lower thoracic and upper lumbar vertebrae with kyphoscoliosis.

CASE 2. A married man, forty-eight years old, a building contractor, consulted the Mayo Clinic first in 1940 because of a feeling of upper abdominal fullness. A diagnosis of "biologic inadequacy" was recorded in his history. His gastro-intestinal complaint was thought to be functional. In 1960, he returned with the same complaint and, in addition, the complaint of back discomfort, which he described in such vague terms as "burning" and "aching".

He presented no evidence of easy bruising and had no dislocation of his joints. He was sixty-nine and a half inches tall but weighed only 132 pounds. His neck appeared to be longer than

normal, and his hips were hyperextended when he was standing. He had relaxed flat feet, mild genu recurvatum, and cubitus recurvatum (Fig. 2-A). He could touch his thumb to his forearm and had loose, smooth, thin skin which could be easily stretched out two or three inches from his body (Fig. 2-B). There was loss of the normal upper thoracic kyphosis associated with the marked lower thoracic kyphosis characteristic of this syndrome.

Roentgenographic examination again allowed easy visualization, on the lateral view, of all the cervical vertebrae and the first three thoracic segments (Fig. 2-D). The thoracic spine was ramrod straight, without the usual thoracic curve (Figs. 2-E and 2-F). The lumbar spine had the usual lordosis and was not flattened, as in Case 1. The anterior wedging of the lower thoracic vertebrae was very prominent, however, and there was hypertrophic spurring anteriorly (Fig. 2-F). The chest, as seen in Figure 2-E, showed deformities similar to those seen in Case 1, with some increase in the downward sloping of the upper ribs, but the changes were not as marked.

## COMMENT

Thoracolumbar kyphoscoliosis in the Ehlers-Danlos syndrome, with anterior wedging of the vertebrae in this region, was only recently described by Macfarlane. The two patients described here confirm this finding. In addition, they present other skeletal abnormalities not previously described, namely, a long, giraffe-like neck, a downward sloping of the ribs of the upper part of the thorax, and a tendency to reversal of the normal cervical, thoracic, and lumbar spinal curves.

All of these changes presumably relate to the connective-tissue defect in the Ehlers-Danlos syndrome. They have not been specifically described in other general affections of the skeleton, but may occur in disorders other than this syndrome. Epiphysitis of the spinal column has been reported in the Marfan syndrome, and contributes to the kyphoscoliosis often seen in it [4]. Patients with osteogenesis imperfecta present a round back, and the thorax may be conical or shaped like a beehive. Kyphoscoliosis also may be observed in osteogenesis imperfecta. Patients with Hurler's syndrome (gargoylism) present thoracolumbar kyphoscoliosis, but this is characterized by a rather acute angle and is due to posterior displacement of one vertebra, which becomes acutely wedged anteriorly and produces a gibbus. The Morquio-Brailsford type of chondro-osteodystrophy is characterized by a similar change. The thoracic cage in craniocleidodysostosis appears very much like that seen in the two patients described here. The ribs of the upper part of the thorax slope downward to a greater degree than normal.

It appears, therefore, that heritable defects of mesenchyme may produce many skeletal changes such as the ones reported here in the Ehlers-Danlos syndrome.

## REFERENCES

1. Bruno, M.S., and Narasimhan, P.: Ehlers-Danlos Syndrome. A Report of Four Cases in Two Generations of a Negro Family. New England J. Med., **264:** 274–277, 1961.
2. Danlos, H.: Un cas de cutis laxa avec tumeurs par contusion chronique des coudes et des genous (xanthome juvénile pseudo-diabétique de M.M. Hollopeau et Macé de Lépinay). Bull. Soc. Française Dermatol. et Syphilig., **19:** 70–72, 1908.
3. Ehlers: Cutis laxa, Neigung zu Haemorrhagien in der Haut, Lockerung mehrerer Artikulationen. Dermat. Zeitschr., **8:** 173–174, 1901.
4. Fairbank, H.A.T.: An Atlas of General Affections of the Skeleton. Edinburgh, E. and S. Livingstone, Ltd., 1951.
5. Macfarlane, I.L.: Ehlers-Danlos Syndrome Presenting Certain Unusual Features. J. Bone and Joint Surg., **41-B:** 541–545, Aug. 1959.
6. McKusick, V.A.: Heritable Disorders of Connective Tissue. Ed. 2. St. Louis, The C. V. Mosby Co., 1960.

# Carpal Osteochondroma

BY KINGSBURY G. HEIPLE, M.D., CLEVELAND, OHIO

*From the Division of Orthopaedic Surgery, University Hospitals of Cleveland, and Western Reserve University School of Medicine, Cleveland*

Osteochondromata are familiar lesions in most of the long bones. They occur typically at the juxta-epiphyseal area of the metaphysis and appear as sessile or stalked bone protuberances arising smoothly from the cortex. Grossly and histologically, they are covered by a cap of benign cartilage which will show varying degrees of cellular activity. Before epiphyseal closure, they usually show active evidence of cartilaginous proliferation, a crude type of columnation of the chondrocytes, and calcification and replacement of the deeper portions of the cartilage by the apparently normal bone of the stalk. After normal growth has ceased, osteochondromata tend to become quiescent, the cartilage cap becomes thinner and less cellular and, occasionally, may even disappear entirely. When reactivation of growth occurs in a pre-existing lesion or one arises *de novo* in adult life, the possibility of sarcomatous degeneration must be kept in mind. The incidence of malignant change is quite low, however; it is less than 1 per cent in solitary lesions, but is probably higher in patients with hereditary multiple osteochondromata [1,4].

Sir Arthur Keith suggested in 1919 that the primary defect in multiple exostoses or diaphyseal aclasis is the presence of multiple defects in the periosteal cuff of the metaphysis with failure of the normal remodeling process as a consequence. This would allow portions of the proliferating epiphyseal cartilage to survive and continue marginal growth. This concept does not allow for the occurrence of osteochondroma on any bone entirely preformed in cartilage or derived from membranous bone. An alternative concept is that the lesion arises from cartilaginous rests in the periosteum or similar rests in tendon attachments to bone[1]. It may well be that both mechanisms operate, some form of the latter mechanism accounting for the occurrence of these lesions in non-epiphyseal bones.

Even if the theory of cartilaginous-rest activation is accepted for solitary osteochondromata, their incidence on non-epiphyseal bones remains unexplainably low. The incidence may be related to the total area of periosteal surface available; this is certainly small in the carpal bones as compared with the long bones or even the larger tarsal bones. It might still reflect a basic difference in the mechanism by which these bones are formed, with the epiphyseal cartilage being the major source of such rests when they do occur.

Some measure of the relative incidence in various bones can be obtained from Geschickter and Copeland in their tabulation of 318 patients with osteochondroma, both single and multiple. The calcaneus was the most common tarsal bone to be involved, with twenty-seven cases. This is consistent with its large size and the presence of an epiphysis; the calcaneus cannot be considered to be entirely preformed in cartilage like the rest of the tarsal and carpal bones. The talus was involved in three cases, and several other isolated reports of occurrence from this bone have been made [6,7]. The tarsal navicular was involved once and the sternum once. The only occurrence in a carpal bone in Geshickter and Copeland's series was a lesion arising from the carpal navicular in a white man, twenty-one years old. This arose in the right wrist, was of four months' duration before excision, and had had no recurrence at follow-up nine and one-half years later.

FIG. 1

Anteroposterior roentgenogram of the wrist. The lesion is seen projecting beyond the radial limits of the carpus, with a trabecular bone pattern. The ossicle distal to the ulnar styloid process is felt to represent either ossification following old trauma or an ununited fracture of the styloid process.

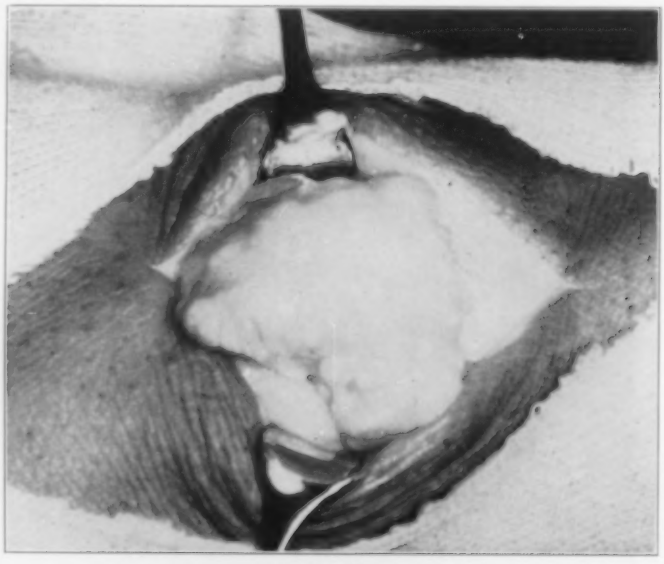


FIG. 2

Gross appearance of the lesion at surgery. The glistening, smooth, but lobulated appearance of the cartilaginous cap is evident.

The only other report of occurrence arising from a carpal bone that could be found was the mention of four cases in a series of 232 exostoses reported by Meyerding. None of these was specified as to exact bone of origin or other details.

## CASE REPORT

A.C., a Negro machine operator, sixty-three years old (U.H. #746-104), was seen in staff-service consultation in February 1960, during the course of a hospitalization for repair of a post-appendectomy incisional hernia. Other than his admission complaint, his history and physical and laboratory findings were within normal limits, apart from obesity, asymptomatic hypertension (180 systolic, 130 diastolic), and moderate cardiomegaly. There was a four-centimeter, osseous, hard mass on the radial aspect of the dorsum of the right wrist. It was non-tender and firmly fixed to the deeper structures, but not attached to the overlying skin. The patient had first noted this mass approximately twelve years previously and said that it had very slowly enlarged over that period of time. It was occasionally annoying in his work and subject to some trauma, but was not painful. The overlying skin was of normal texture, there was no warmth or redness, and no bruit was audible. There was no history of similar lesions in the family, and this was the only such lesion found on the patient.

FIG. 3

Photomicrograph (× 100) of a representative section in a plane perpendicular to the surface of the lesion. The cells are small and regular and there are no double nuclei. There is evidence, however, of some columnation of the cells with calcification and active enchondral-bone formation consistent with the clinical history of enlargement.

A roentgenogram of the wrist obtained at this time showed the bone mass seen in Figure 1. The size of the lesion and the irregularity of the carpal contours made its attachment impossible to determine before operation. Despite the roentgenographic appearance of normal bone, it was felt that sheer size and a history of slow enlargement justified its removal. Because of its unusual location, the preoperative diagnosis was that of either ossified hematoma or synovial osteochondroma, since I was not aware that typical osteochondroma could occur in this location.

The area was explored under brachial-block anesthesia on February 25, 1960. The mass immediately presented itself as a lobulated, smooth, cartilage-covered tumor fixed to underlying bone. The sensory branch of the radial nerve was displaced volarly and the extensor pollicis longus tendon dorsally (Fig. 2). The stalk of attachment was only three to four millimeters long and barely four to five millimeters in diameter. After the stalk had been sectioned with an osteotome, inspection of the underlying carpal bones revealed that its point of attachment had been the dorsal surface of the greater multangular. The cancellous interior of the multangular was in direct continuity with the core of the stalk without any multangular cortex across the base to indicate that the attachment might have been secondary. There were several small, free cartilage bodies immediately adjacent to the major mass, which may have been broken off in previous episodes of trauma. The incision healed *per primam* and the patient had regained full use of his hand and

wrist by four weeks after operation with only slight limitation of volar flexion of the wrist. At the most recent follow-up, February 8, 1961, there was no sign of local recurrence and the patient was completely asymptomatic in regard to his hand and wrist.

Histological sections of the osseous lesion (Fig. 3) showed a thin cartilage cap covering normal cancellous bone filled with fatty marrow. Sections of the free cartilage bodies revealed somewhat more cellular cartilage very similar to that seen in enchondromata; there was no evidence of malignant change in any of the sections.

## DISCUSSION

The greater multangular is a quite small bone and a considerable portion of its surface comprises its articulations with the first and second metacarpals, the lesser multangular, and the navicular. Not more than half of its surface is available for the origin of an osteochondroma. It is not too surprising that an osteochondroma in this location should be unusual. Apparently this is the only case that has been described in this location.

If one subscribes to the theory that these tumors occur only at sites of tendinous attachments, the only explanation that can be given for this lesion is that occasionally there is a tendinous slip from the abductor pollicis longus inserted on the dorsum of the greater multangular [2]; it is perhaps significant that this lesion arose from the dorsal side, but nothing to suggest a pre-existing tendinous attachment was observed at operation. Normally, the greater multangular is free of tendinous attachments, although it does give partial origin to three of the thenar muscles.

Although the history of progressive enlargement in an adult would suggest malignant change, the histological sections gave no suggestion of this and thus far there has been no sign of recurrence. It cannot be proved that this lesion did not have its genesis in childhood, but the location was subcutaneous and it would be surprising if it escaped notice until the patient had reached the age of fifty.

## SUMMARY

1. The etiology and incidence of osteochondromata, with particular reference to the bones entirely preformed in cartilage, has been discussed briefly.

2. A case of a large, solitary osteochondroma arising from the greater multangular is reported. This is the only case that has been reported and is only the fifth such lesion on any carpal bone that has been recorded to my knowledge.

## REFERENCES

1. Geschickter, C.F., and Copeland, M.M.: Tumors of Bone. Ed. 3, pp. 37–78. Philadelphia, J.B. Lippincott Co., 1949.
2. Gray, Henry: Anatomy of the Human Body. Ed. 27, pp. 252, 509. Edited by C.M. Goss. Philadelphia, Lea and Febiger, 1959.
3. Keith, Arthur: Studies on the Anatomical Changes which Accompany Certain Growth-Disorders of the Human Body. J. Anat., **54**: 101–115, 1919.
4. Lichtenstein, Louis: Bone Tumors. St. Louis, The C.V. Mosby Co., 1952.
5. Meyerding, H.W.: Exostosis. Radiology, **8**: 282–288, 1927.
6. Milch, R.A.: Osteochondroma of the Astragalus. Am. J. Surg., **87**: 145–148, 1954.
7. Rook, F.R.: Intra-Articular Osteochondroma of the Astragalus. Am. J. Surg., **85**: 807–810, 1953.

# Bone Destruction Associated with Aminonucleoside Administration

BY A. D. JOHNSTON*, M.D., AND RICHARD H. FOLLIS, JR., M.D., WASHINGTON, D. C.

*From the Veterans Administration Central Laboratory for Anatomical Pathology and Research, Armed Forces Institute of Pathology, Washington*

Much remains to be learned concerning the intimate details of the process whereby bone is destroyed. Clinically, evidence of increased osteolytic activity is observed as a result of severe inanition, primary or secondary hyperparathyroidism, hyperthyroidism, and several other miscellaneous conditions [4]. In the experimental animal excessive amounts of vitamins A or D [1], parathormone [9], and certain chelating agents [7] lead to osteolysis.

Recently, Selye [12,13] reported the development of "osteitis fibrosa-like" lesions in the bones of rats which had been treated with an aminonucleoside of the antibiotic puromycin. Since such lesions appeared even after ablation of the parathyroid and thyroid glands, Selye concluded that they were the result of a direct action of the drug on bone.

This aminonucleoside has a species specific nephrotoxic effect on rats, which has been widely studied [3,6,11]. The aminonucleoside of puromycin is a chemical homologue of yeast adenylic acid. It may block the formation of adenosine triphosphate *in vitro* [11]. Its nephrotoxic action can be experimentally inhibited by adenine [8]. Hence, it has been concluded that this drug is an antimetabolite which interferes with purine metabolism.

The effects of such an agent presented an opportunity to study in more detail the early phases of bone destruction, together with the influence of progressive renal disease; such is the purpose of this presentation.

## MATERIALS AND METHODS

Two dosage groups of albino rats weighing fifty-five to sixty grams were injected subcutaneously each day with one or two milligrams of the aminonucleoside of puromycin in one cubic centimeter of distilled water. The number of animals in each group, dosage regimen, times of sacrifice, and other manipulations are recorded in Table I.

In all instances, rat chow and water were given *ad libitum*. Some animals, as indicated in Table I, were sacrificed serially from four hours to twelve days after the first injection; in others, the drug was discontinued after four or eight injections and the animals were sacrificed at the stated intervals or allowed to die. Body weights, autopsy findings, and food and water intake were recorded in about half the animals so treated, as well as for the normal controls.

Thyroparathyroidectomized and parathyroidectomized rats were subjected to similar dosage schedules for comparison with the experimental and control animals. Successful removal of the parathyroids was checked by inspection under a dissecting microscope and by serial sections of the neck organs at sacrifice or autopsy. The bones were fixed in neutral formalin and sectioned, in most instances, without decalcification.

## RESULTS

Aminonucleoside administration was attended by significant alterations in

* Special Research Fellow, United States Public Health Service, 1958–1960.

TABLE I

ANIMAL DATA

| | No. of Animals | Aminonucleoside Daily Dose | Times of Sacrifice | Recorded Data |
|---|---|---|---|---|
| A. Stock cages | | | | |
| | 30 | 1 mg. per day | 4, 8, 12 hrs. Days 1 to 15 | Body weights Autopsy findings |
| | 30 | 2 mgs. per day | 4, 8, 12 hrs. Days 1 to 10 | Body weights Autopsy findings |
| | 10 | Controls | Days 11 and 16 | Body weights Autopsy findings |
| | 5 | 2 mgs. per day × 4 | Days 13, 18, 28 | Body weights Autopsy findings |
| | 5 | 1 mg. per day × 8 and 12 | Days 15, 18, 28 | Body weights Autopsy findings |
| B. Metabolic cages | | | | |
| | 30 | 1 mg. per day | Days 13 to 15 | Body weights Autopsy findings |
| | 15 | 2 mgs. per day | Days 1 to 5 | Food, water intake Urine and fecal output |
| | 9 | Controls | Day 15 | |
| C. Special handling Stock cages | | | | |
| 1. Thyroparathyroidectomy | 8 | 2 mgs. per day | Days 1 to 6 | Body weights Autopsy findings |
| | 2 | Controls | Days 5 and 6 | |
| 2. Parathyroidectomy | 8 | 2 mgs. per day | Days 1 to 6 | |
| | 2 | Controls | Days 5 and 6 | |
| 3. Colchicine (0.5 mg. per gm. of body weight) | 4 | 1 mg. | 24 hrs. | Mitotic figures in epiphyseal plates of tibia |
| | 4 | 2 mgs. | 24 hrs. | |
| | 2 | Controls | 24 hrs. | |

weight gain. This, as might be expected, exerted an influence on the pattern of the bone lesions. This influence could be assessed by comparing body weights with histological examination of the proximal epiphyseal cartilage of the tibiae.

The weight curves (Figs. 1-A and 1-B) indicate that growth continued, albeit at a modified rate, for five to six days in the group receiving two milligrams per day and nine to ten days in those animals receiving one milligram of the drug daily. Then failure to gain occurred but was obscured by the accumulation of ascitic fluid and edema as a result of renal insufficiency. Anasarca was grossly evident on about the seventh day with the higher dosage and on about the ninth day with the lower dosage. In Figure 1-B some indication of the quantity of the ascites is given by the lowest curve which represents the weight of the sacrificed animal after removal of ascitic and pleural fluid.

The epiphyseal cartilage exhibited changes soon after the drug was administered. Within four hours of an injection of two milligrams of aminonucleoside, detectable alterations were found (Figs. 3-A and 3-B). Similar changes appeared twelve hours after a one-milligram dose. The entire cartilaginous plate was widened. The sharp distinction between proliferative and maturing zones was lost. Instead, an apparent acceleration of maturation resulted in the conversion of almost the entire width of the growth plate to a more or less uniform zone of hypertrophic cartilage cells. A further increase in the thickness of the plate was found in the animals sacrificed during the ensuing twenty-four to forty-eight hours. The number of mitotic figures in sections from these animals was approximately double that in the sections from controls of similar weight after dosage with colchicine for the purpose of arresting mitosis. Thus, there was early evidence of proliferative activity of cartilage cells (Fig. 4).

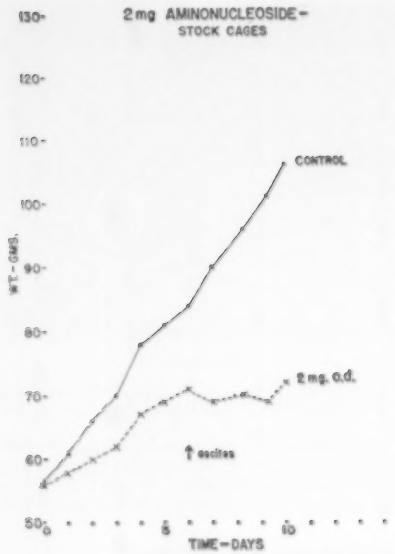



FIG. 1-A

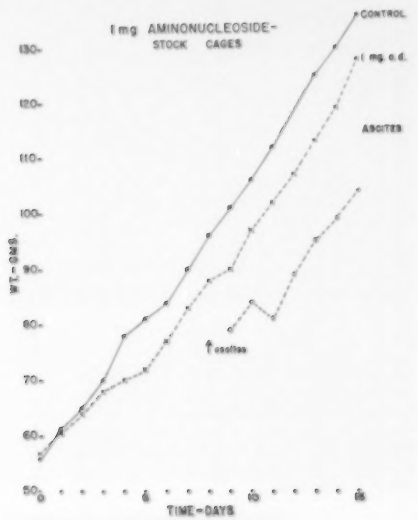



FIG. 1-B

Figs. 1-A and 1-B: Weight curves at the time of sacrifice of animals receiving two (Fig. 1-A) and one (Fig. 1-B) milligram of aminonucleoside per day compared with the weights of their controls. The lowest curve in Fig. 1-B represents the weight of each animal at sacrifice after removal of ascitic and pleural fluid. The deviation from the controls reflects diminished growth rates (confirmed microscopically).

Fig. 2: Weight curves of animals receiving one milligram of aminonucleoside daily and of their controls and the curves for the food intake of both groups of animals. Failure to maintain control body weights is correlated with reduced food intake of the injected animals.

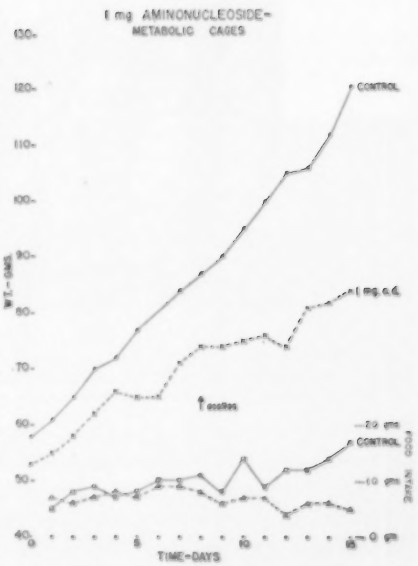



FIG. 2

Multinucleated cells (chondroclasts) appeared in increasing numbers just beneath the cartilage toward the end of this period (Fig. 6-A). Their presence was associated with an acceleration of cartilage removal.

This spurt of cartilaginous growth was short-lived; it was not reflected in the weight curves. Whether the bones increased in length over the normal at this time has not been determined. Mitotic activity soon subsided, after which the epiphyseal plate became thinner until the fifth day in the group receiving two milligrams of aminonucleoside (Fig. 5-B) and until the eighth to ninth days in rats on a daily dose of one milligram of aminonucleoside. At this time the distinction between zones that was previously obliterated reappeared. The maturing or hypertrophic zone, however, occupied approximately 75 per cent of the width of the epiphyseal growth plate, as compared to a value of 30 to 40 per cent in the control animals. The matrix about these hypertrophic cartilage cells thereafter

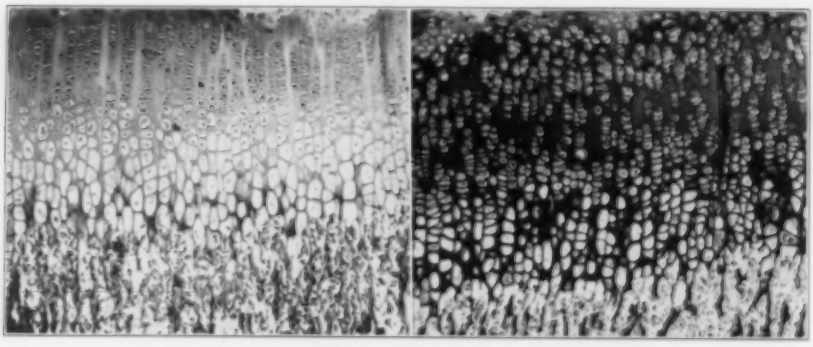


FIG. 3-A FIG. 3-B

Fig. 3-A: Photomicrograph (× 70) of tibial epiphyseal cartilage from a normal rat weighing fifty-five grams (three to four weeks old). Note the thickness of the cartilage and the distinction between secretory and hypertrophic zones.

Fig. 3-B: Photomicrograph (× 70) of the tibial epiphysis from a rat of the same age as that shown in Fig. 3-A. This animal received two milligrams of aminonucleoside four hours before sacrifice. The epiphyseal plate is thickened. The hypertrophic zone occupies practically the entire thickness of the growth cartilage. Note the demarcation between secretory and hypertrophic zones is obscured.

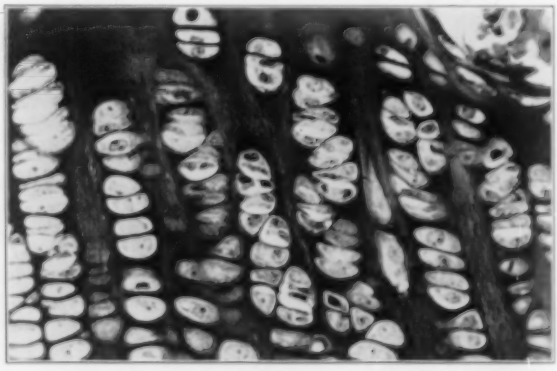


FIG. 4

Photomicrograph (× 150) of tibial epiphyseal cartilage from a rat which had received two milligrams of aminonucleoside daily for two days before sacrifice. A mitotic figure is shown a little to the right of center. A number of lacunae contain more than one cell.

was greatly reduced in amount and the epiphyseal plate became thinner. The multinucleated cells beneath the cartilage also decreased in numbers.

The changes in the cartilage roughly paralleled the changes in weight. The alterations in growth, which are reflected by the changes in the epiphyseal cartilage, were more clearly indicated in the weight curves of animals which received one milligram of aminonucleoside and which were kept in metabolic cages (Fig. 2). A smaller accumulation of ascitic fluid in these animals allowed closer approximation of true body weight but deceleration of growth occurred earlier (fifth to seventh days) than in animals maintained in stock cages. Since rats on this lower dosage survived for longer periods, which were extended by cessation of drug administration (Table I), the final suppression of growth was even more striking. Figure 7 shows the epiphyseal plate of one such animal which died sixteen days after the twelfth daily dose of aminonucleoside.

The alterations in the metaphyseal area followed analagous patterns. Four hours after a two-milligram dose of aminonucleoside and twelve hours after a

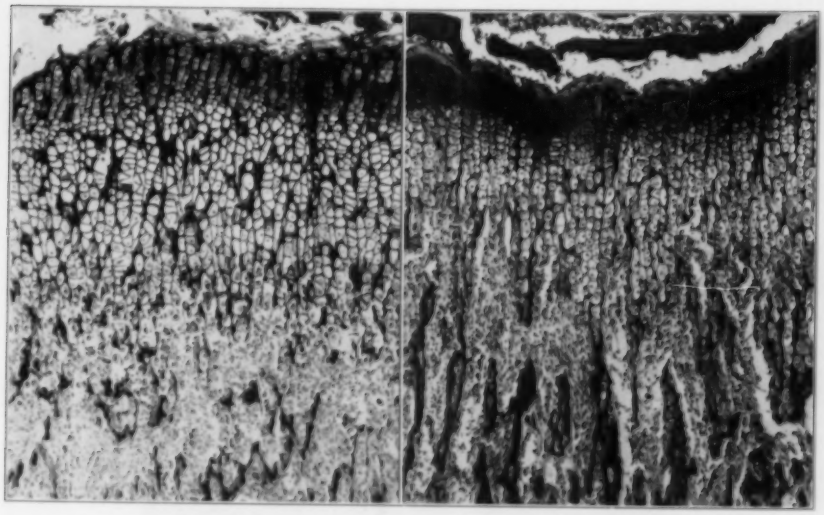


FIG. 5-A FIG. 5-B

Fig. 5-A: Photomicrograph (× 65) of tibial epiphyseal cartilage and metaphysis from a rat which had received two milligrams of aminonucleoside daily for three days before sacrifice. The cartilage plate is increased in width with a disproportionately wide hypertrophic zone. There is less bone than normal in the upper metaphyseal spongiosa.

Fig. 5-B: Photomicrograph (× 65) of epiphyseal cartilage and metaphysis from a rat which had received two milligrams of aminonucleoside daily for five days. Note narrowing of the epiphyseal cartilage, rarefaction of the upper metaphyseal spongiosa, and cellularity of the marrow.

FIG. 6-A FIG. 6-B

Fig. 6-A: Photomicrograph (× 142) of the upper metaphyseal spongiosa where it borders on the tibial cartilage plate from a rat which had received two milligrams of aminonucleoside daily for three days. Note increased cellularity and increased number of multinucleated cells in proximity to the spicules of calcified cartilaginous matrix.

Fig. 6-B: Photomicrograph (× 142) of upper metaphyseal spongiosa bordering on the tibial cartilage plate from a rat which had received two milligrams of aminonucleoside daily for five days. Note the cellularity with many rounded and fusiform osteoblast-like cells.

one-milligram injection, hypertrophy of osteoblast-like cells was apparent, and the sinusoids in the marrow spaces were encroached upon by these enlarged cells. In the ensuing twenty-four to forty-eight hours hyperplasia occurred, as evidenced by an increasing number of mitotic figures (Fig. 8) and the appearance of increased cellularity in the metaphyseal area. By the third day in rats receiving two milligrams and by the fifth or sixth day in rats receiving one milligram of aminonucleoside, this cellular proliferation and hypercellularity had extended to the more distal metaphyseal trabeculae and to the remaining metaphyseal marrow spaces.

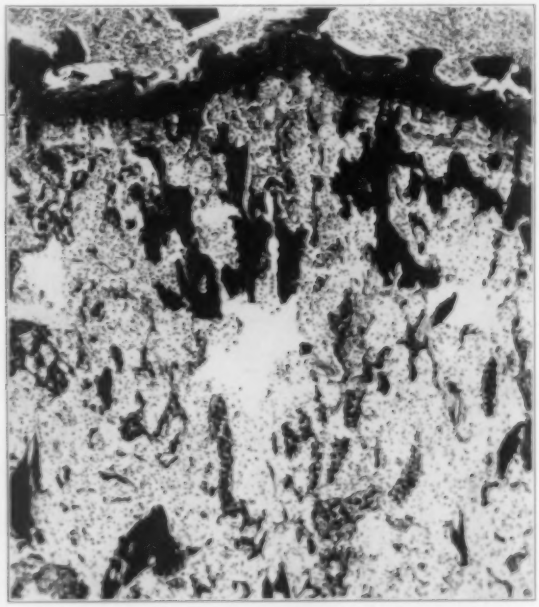


FIG. 7

Photomicrograph (× 70) of proximal epiphyseal plate and metaphysis of the tibia from a rat which received one milligram of aminonucleoside daily for twelve days and died sixteen days after cessation of drug (a total of twenty-eight days after the first injection). Note decrease in width of cartilage plate, virtual absence of normal hematopoiesis, and atrophy of cellular marrow.

At about this same time, however, atrophy of individual osteoblastic cells was observed and decreasing mitotic activity became evident. The cells began to lose their plump polyhedral appearance and they were progressively reduced to fusiform structures resembling fibroblasts. Their hitherto prominent Golgi-like vacuolation disappeared. The initiation of these changes roughly coincided with the earliest microscopic evidence of renal tubular damage, with the formation of protein casts on the third day in rats on the higher and on the sixth day in rats on the lower aminonucleoside dosage.

Metaphyseal alterations were most striking on the fifth day in rats receiving two milligrams (Figs. 5-B and 6-B) and on the eighth or ninth days in rats receiving a one-milligram injection of aminonucleoside. Osteoblast-like cells were crowded in the marrow spaces and clusters of these cells were occasionally found in trabecular defects. Osteoclasts were somewhat more prominent in contrast to the atrophic osteoblastic cells. There was, however, no great increase in the number of osteoclasts.

These findings indicate that there was an increasing discrepancy between the degree of cellularity and the amount of bone present. The bone trabeculae were strikingly thinner despite the presence of an increased number of osteoblast-like cells and the absence of an undue osteoclastic reaction. Osteoblastic impotence is suggested by the presence of a lattice of calcified cartilage matrix devoid of appositional bone in the superior part of the metaphysis.

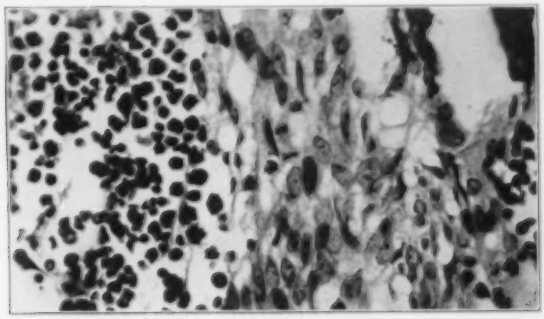


FIG. 8

Photomicrograph (× 200) from metaphysis of a rat which had received one dose of two milligrams of aminonucleoside twenty-four hours before. Note mitotic figure.

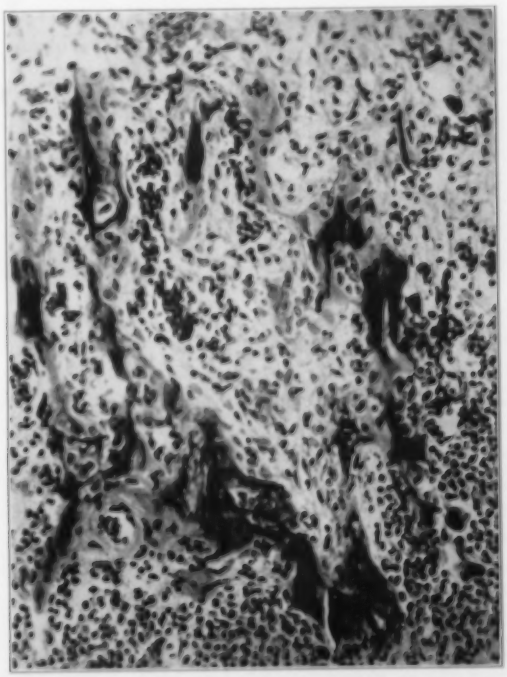


FIG. 9

Photomicrograph (× 130) of the lower part of the metaphysis from a rat which had received two milligrams of aminonucleoside daily for nine days. Note the presence of osteoid and the transformation of osteoblast-like cells to a "myxoid" type of cell.

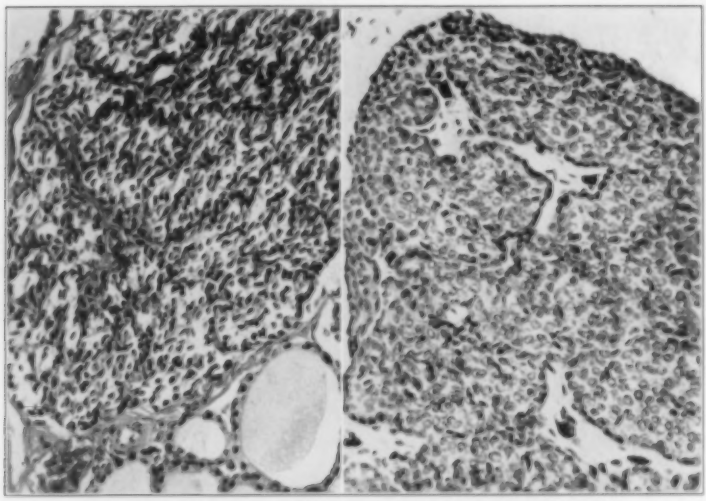


FIG. 10-A FIG. 10-B

Fig. 10-A: Photomicrograph (× 200) of a parathyroid gland from a normal rat.

Fig. 10-B: Photomicrograph (× 200) of a parathyroid gland from a rat which had received two milligrams of aminonucleoside daily for nine days. Note increase in size of cells and organoid grouping.

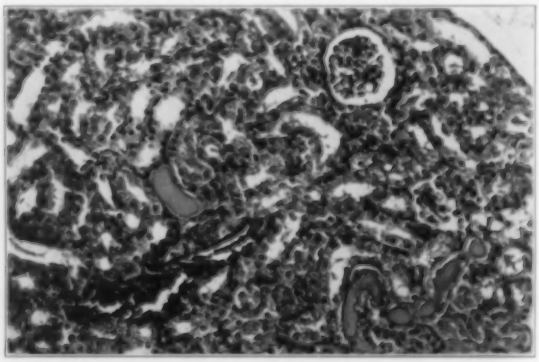


FIG. 11

Photomicrograph (× 150) of a kidney from an animal which had received two milligrams of aminonucleoside daily for three days. Note coagulated material in the tubules and the tubular dilatation.

From this time on, and concurrent with the previously indicated deceleration of growth, the osteoblastic cells atrophied rapidly to stellate forms, relatively devoid of cytoplasm and resembling primitive myxoid connective-tissue cells (Fig. 9). By the eighth to tenth day in rats on the higher dosage and the twelfth to fifteenth day in rats on the lower dosage these changes were manifest. Since the marrow became progressively less cellular during this phase, the disproportion between cellularity and bone matrix became quantitatively readjusted.

Little bone appeared to be formed during these days. Osteoblastic activity had not ceased, however, since small amounts of osteoid were seen (Fig. 9). Osteoid was first noticeable in each dosage group a few days before the onset of externally evident ascites and edema—again roughly coincident with the earliest histological evidence of renal disease. After the onset of ascites and edema, progressive diminution of osteoid was observed until death of the animal.

The hematopoietic bone marrow also showed cellular hypertrophy and hyperplasia after the early phase of aminonucleoside administration. Thereafter, a progressive hyperemia and sinusoidal dilatation displaced the hematopoietic marrow. This was accompanied by a shift in marrow-cell population to less well differentiated cell forms.

In addition to the lesions in bone, alterations in the parathyroid, thyroid, and adrenal glands deserve mention.

The parathyroid glands (Figs. 10-A and 10-B) remained histologically unchanged until about the fifth, sixth, or seventh day in rats on daily dosage of two milligrams of aminonucleoside. At that time, when growth was decelerated and renal failure impended, progressive changes appeared in these glands consisting of cellular enlargement and a "water-clear" vacuolation of the cells. A tendency for the cells to be arranged about blood vessels became increasingly manifest thereafter. The cells on the periphery of these organoid clusters acquired a basophilic cytoplasm. This hypertrophy and basophilism continued to become more widespread and, in one instance (Fig. 10-B), the entire gland was composed of these organoid clusters. No mitotic activity was demonstrable, even after treatment of the animals with colchicine. Some infiltration with mast cells accompanied the minor structural alterations observed in the supportive tissues. Thyroparathyroidectomy and parathyroidectomy definitely augmented the bone lesions described, accelerating their onset and intensity.

The renal lesions have been described by others[3,6]. The earliest changes appeared in the tubules at three days in the rats on the two-milligram daily dose (Fig. 11) and at five days in the rats on the one-milligram daily dosage of aminonucleoside. Preceding these changes, however, an accelerated mitotic activity in both proximal and distal convoluted tubules appeared. This activity continued with abating intensity until renal failure, signaled by ascites and edema, supervened. Despite some variations in cellularity and indefinite alterations in the basement membranes, the glomeruli were relatively unchanged except in the long-term survivors on lower dosage. Vascular alterations followed the same indefinite pattern.

The thyroid gland displayed a progressive atrophy coincident with the deceleration of growth. Loss of height of the epithelial cells was followed by a more gradual diminution in colloid. More prolonged survival on continuous dosage was correlated with more pronounced evidence of thyroid atrophy.

The adrenal glands, in view of their demonstrated participation[2] in the symptoms, that is, ascites, of aminonucleoside-induced renal insufficiency, were regarded with some interest. Adrenal weights, expressed as milligrams per gram of body weight, plotted against time at both dosage levels, confirmed the histological impression of adrenal-cortical hypertrophy and hyperplasia between the ninth and the fourteenth days in rats receiving one milligram daily and between the fifth and the eighth days in rats receiving two milligrams daily. These hypertrophic changes preceded the external manifestations of ascites and edema by a few days and were nearly coincidental with the deceleration of growth.

## DISCUSSION

The availability of a relatively simple chemical compound of known structure, such as this aminonucleoside of puromycin, would appear to offer a unique opportunity to study morphological sequences which accompany bone destruction *in vivo* and, in addition, to begin to correlate these alterations with biochemical patterns in serum and urine. Our studies confirm the observations of Selye that this drug produces an "osteitis fibrosa-like" lesion[13,14]. Moreover, the amino-

nucleoside exerts its effect in the absence of the parathyroid glands. Selye used the term *osteitis fibrosa* in a broad sense to characterize those skeletal diseases in which anatomically excessive cellular destruction of bone is found. With this definition we are in agreement.

The first effect of the administration of the drug apparently is to stimulate proliferation of chondrocytes as well as osteoblast-like cells. The epiphyseal plate becomes widened. Increasing cellularity of the metaphysis takes place. Osteoclasts which are found in proximity to cartilage as well as to bone are present in increasing numbers. In these respects (cartilage-cell growth and increase in the numbers of osteoblast-like cells and osteoclasts), the histological picture resembles that which may be observed after certain doses of parathyroid extract. The thin lattice of calcified cartilage matrix devoid of bone (Fig. 6-B) makes it clear that the increased cellularity of the metaphysis leads to osteolysis rather than excessive bone-matrix production. As has been noted, this phase of the disturbance lasts for varying periods, depending on the dose of the drug administered.

This period of cellular hyperactivity is followed by one of decreasing proliferation of cartilage and bone cells. The epiphyseal plate becomes increasingly narrow, a finding which certainly connotes growth retardation. Moreover, the mesenchymal cellular elements of the metaphysis and endosteum of the cortex become more stellate and appear to have relatively little functional activity in terms of new-matrix formation. That they have some function, however, is evident by the appearance of osteoid, that is, new uncalcified bone, and the increasing rarefaction of the metaphyseal trabeculae which is doubtless indicative of continuing destructive activity. Thus the cells morphologically appear inactive; the relative lack of any new matrix nearby confirms this state. When an animal dies as a result of the effects of the drug, autopsy reveals that growth of epiphyseal cartilage and bone appears to have virtually ceased.

Since it is well known that aminonucleoside administration to the rat leads to widespread renal damage at some time during the course of these dynamic changes in bone, the effects of renal insufficiency must soon begin to play a role. It has not been established exactly at what point this occurs. Histologically, the kidneys do not exhibit morphological alterations for a number of days. We are aware, of course, of the electron microscopic observations on the glomerulus which demonstrate damage at an earlier time [15]. Decisive observations on the bones from nephrectomized animals treated with aminonucleoside have not as yet been reported. Nor have sufficient studies of calcium and phosphate excretion been carried out on the urine from animals treated with the drug to help in interpreting the alterations in the bone. One might suspect that the appearance of osteoid at a certain stage in the development of the skeletal lesions indicates a relationship to progressive renal insufficiency. Rickets or osteomalacia may, of course, be a prominent feature of chronic renal disease in man [5].

Hyperplasia of the parathyroid is to be expected when there is functional impairment of the kidneys [10]. So, too, is adrenal hyperplasia, a non-specific reaction to many forms of trauma, to be expected [14]. Whether either of these glands have a direct effect on the alterations observed in the skeleton must await further study.

## SUMMARY

The effect of aminonucleoside of puromycin on growing bone in the rat is characterized first by stimulation with accelerated maturation of bone and cartilage cells. This change is climaxed by a metaphyseal lesion identical with osteitis fibrosa produced by other means. Cellular growth activity practically

ceases thereafter. The appearance of excess osteoid after the microscopically determined advent of renal lesions suggests a relationship between the two. After growth ceases, anorexia, thyroid atrophy, and hyperplasia, first of the adrenal glands and finally of the parathyroid glands, make further assessment of the pathogenesis of the bone lesions extremely difficult.

REFERENCES


1. Barnicot, N. A.: Local Action of Calciferol and Vitamin A on Bone. Nature, **162:** 848–849, 1948.
2. Das Gupta, D.; Kalant, N.; and Giraud, C. J. P.: Experimental Aminonucleoside Nephrosis (II): Effect of Adrenalectomy on Fluid Retention of Aminonucleoside Nephrosis. Proc. Soc. Exper. Biol. and Med., **100:** 602–604, 1959.
3. Fisher, E. R., and Gruhn, J.: Aminonucleoside Nephrosis in Rats. A.M.A. Arch. Pathol., **65:** 545–553, 1958.
4. Follis, R. H., Jr.: A Survey of Bone Disease. Am. J. Med., **22:** 469–484, 1957.
5. Follis, R. H., Jr., and Jackson, D. A.: Renal Osteomalacia and Osteitis Fibrosa in Adults. Bull. Johns Hopkins Hosp., **72:** 232–241, 1943.
6. Frenk, S.; Antonowicz, I.; Craig, J. M.; and Metcoff, J.: Experimental Nephrotic Syndrome Induced in Rats by Aminonucleoside. Renal Lesions and Body Electrolyte Composition. Proc. Soc. Exper. Biol. and Med., **89:** 424–427, 1955.
7. Gomori, G., and Gulyas, E.: Effect of Parenterally Administered Citrate on the Renal Excretion of Calcium. Proc. Soc. Exper. Biol. and Med., **56:** 226–228, 1944.
8. Hartman, M. E.; Hartman, J. D.; and Baldridge, R. C.: Inhibition of Aminonucleoside Nephrosis by Adenine. Proc. Soc. Exper. Biol. and Med., **100:** 152–155, 1959.
9. Jaffe, H. L., and Bodansky, A.: Experimental Fibrous Osteodystrophy (Osteitis Fibrosa) in Hyperparathyroid Dogs. J. Exper. Med., **52:** 669–694, 1930.
10. Pappenheimer, A. M., and Wilens, S. L.: Enlargement of the Parathyroid Glands in Renal Disease. Am. J. Pathol., **11:** 73–91, 1935.
11. Recant, Lillian; Borowsky, B. A.; and Kessner, D. A.: Aminonucleoside Glomerulonephritis: Morphologic and Metabolic Studies. J. Clin. Invest. **37:** 924, 1958.
12. Selye, H.: Effect of Corticoids upon Skeletal and Renal Changes Produced by Stylomycin Aminonucleoside. Proc. Soc. Exper. Biol. and Med., **96:** 544–547, 1957.
13. Selye, H.: Production of Osteitis Fibrosa by Stylomycin Aminonucleoside in the Parathyroidectomized Rat. Endocrinology, **62:** 287–291, 1958.
14. Selye, H., and Stone, H.: On the Experimental Morphology of the Adrenal Cortex, pp. 44–45. Springfield, Illinois, Charles C. Thomas, 1950.
15. Vernier, R. L.; Papermaster, B. W.; and Good, R. A.: Aminonucleoside Nephrosis. I. Electron Microscopic Study of the Renal Lesion in Rats. J. Exper. Med., **109:** 115–126, 1959.

# Unusual Bilateral Para-Articular Ossification of the Elbows

## Report of a Case

BY C. L. JEANNOPOULOS, M.D., AND EDWARD O. LEVENTEN, M.D.,
WEST HAVERSTRAW, NEW YORK

*From the New York State Rehabilitation Hospital, West Haverstraw*

Para-articular ossification has been observed in various joints as a complication of traumatic paraplegia [1,4,6,12]. It has also been noted following neurological disorders, such as tabes dorsalis, syringomyelia [2], anterior poliomyelitis [3,7,11], and acute multiple sclerosis [8]; and it has been described following burns [5,9,10]. Shroyer, in 1960, reported two patients with para-articular ossification of the posterior aspect of three elbows; he attributed this complication to multiple factors, including soft-tissue trauma and immobility. The purpose of this paper is to document an unusual case of ectopic ossification involving both elbows and causing false ankylosis. The successful surgical management of this case will be described.

Fig. 1

Photograph made on admission five months after injury. The right elbow is fixed in 175 degrees of extension; the left elbow is fixed in 95 degrees of extension.

D. M., a Negro manual worker, twenty-four years old, was in an automobile accident on August 15, 1959. He was admitted to a local hospital where he was reported to have bilateral, symmetrical fractures of both femora, fractures of several ribs, and multiple facial lacerations. There was no swelling or other evidence of trauma to the elbow. He was fully unconscious from the date of injury until August 22, 1959, when he became somewhat responsive; it was not until September 30, 1959, however, that he recovered full consciousness. During this time it became clinically apparent that traumatic quadriplegia had developed. Roentgenograms of the spine showed no fracture or dislocation: the quadriplegia, therefore, was attributed to contusion of the cervical cord.

The fractures of the femoral shafts were treated with Russell's traction. Excellent healing and alignment were obtained, although there was a bilateral symmetrical overriding of the femoral fragments amounting to approximately one and one-half inches. The quadriplegia began to subside spontaneously about four months after injury; and, by February 1960, bladder and bowel control were fully recovered. There was no sensory deficit, and muscle strength showed gradual but progressive improvement.

Despite lack of evidence of soft-tissue or bone injury, both elbows became ankylosed—the right in extension, the left in flexion (Fig. 1). It is to be noted that during the critical period immediately following injury, the patient's right arm was splinted almost continuously for two weeks in full extension on an armboard for intravenous feeding.

On January 25, 1960, the patient was transferred to the New York State Rehabilitation Hospital for evaluation and treatment of the upper extremities. Orthopaedic examination at that time revealed functional strength in both lower extremities. The upper extremities showed the following:

FIG. 2-A

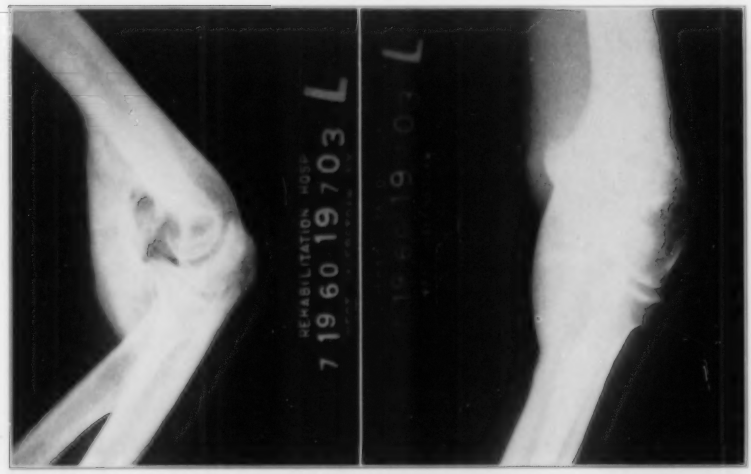



FIG. 2-B

Figs. 2-A and 2-B: Roentgenograms made eleven months after injury showing the right elbow (Fig. 2-A) with bone block on the posteromedial aspect, and the left elbow (Fig.2-B) with a bone bridge extending across the anterior aspect of the joint. Ossification appears to be mature.

In the right upper extremity, the elbow was fixed at 175 degrees of extension with the forearm in mid-position. No pronation or supination was possible. Roentgenograms revealed para-articular ossification extending from the posteromedial aspect of the distal end of the humerus to the medial border of the semilunar notch of the ulna. The joint space was well preserved. There was complete intrinsic-muscle paralysis of the right hand; there was no paralysis or weakness of the other muscles.

In the left upper extremity, the elbow was fixed at 95 degrees of extension, but pronation and supination were each possible to about 15 degrees from the neutral position. Roentgenograms showed a bone bridge extending from the anterior aspect of the distal part of the humeral shaft to the coronoid process and to the volar aspect of the proximal portion of the ulnar shaft, but here also the joint space was well preserved.

The ectopic bone did not appear to be mature at the time of admission, and serial roentgenograms showed progressive ossification (Figs. 2-A and 2-B).

On August 3, 1960, an operation to remove the para-articular ossification in the left elbow was performed. Exposure was made through an anterior S-shaped incision centered over the antecubital fossa. The biceps tendon and the neurovascular bundle were retracted, and the brachialis

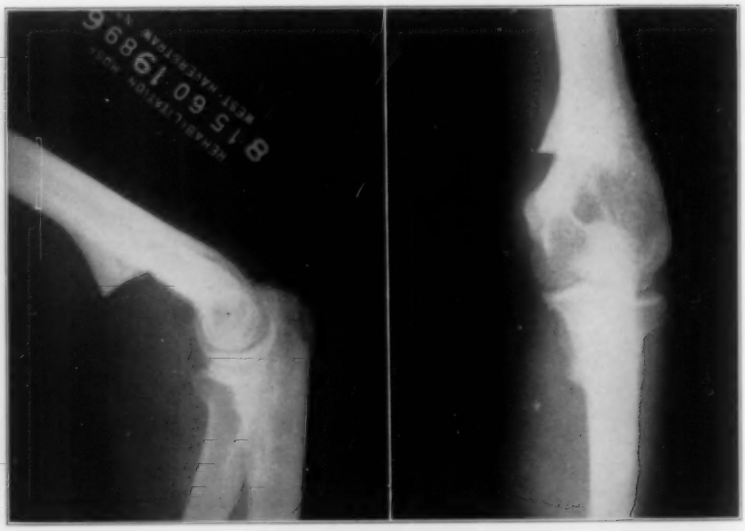


FIG. 3

Roentgenogram of the left elbow after surgery showing terminal attachments of the osseous bridge.

FIG. 4

Active extension and flexion of the left elbow five months after surgery.

muscle was exposed. This was split in the direction of its fibers to reveal the bridge of bone which spanned the elbow joint anteromedially from the distal end of the humerus to the coronoid process. The ectopic bone was loosely attached to, but did not involve, any muscle or capsular structures. The bone bridge was transected and removed with an osteotome except for its terminal attachments (Fig. 3). Following excision, a full range of passive motion was possible. Postoperatively, the elbow was kept in a right-angle plaster splint for ten days. Whirlpool and unassisted active range-of-motion exercises were then commenced. By the fourth week after operation the patient had active extension to 160 degrees and flexion to 90 degrees with moderate pronation and supination. Two months after operation there was essentially a full range of flexion and extension in this elbow (Fig. 4) and normal pronation and supination.

On October 27, 1960, exploration of the right elbow was performed, using a longitudinal incision on the medial aspect of the elbow. The ulnar nerve was identified and retracted anteriorly.

FIG. 5

Roentgenogram of the right elbow made after surgery shows no significant remains of the para-articular ossification.

FIG. 6

Active extension and flexion of the right elbow three months after surgery.

The para-articular bone was noted to extend from the posteromedial end of the humerus to the medial aspect of the olecranon process of the ulna. A small portion of the medial part of the triceps tendon was transsected to facilitate exposure. The ectopic ossification in the right elbow was incorporated into and under the joint capsule. The osseous bridge was osteotomized at its attachments and removed. A full range of passive motion of the joint was then obtained (Fig. 5). The ulnar nerve was transposed anteriorly to avoid leaving it in a bed of raw bone where it might become involved in scar tissue. The postoperative regimen was similar to that for the left elbow. After ten days of splinting at 90 degrees, unassisted active range-of-motion and whirlpool exercises were started. Within four weeks the patient obtained active extension to 170 degrees and flexion to 60 degrees. There was full pronation but supination was limited to 10 degrees from neutral (Fig. 6). The patient was last seen on June 1, 1960. At that time there was no change in the ranges of motion of his elbows. The intrinsic-muscle paralysis of his right hand was also unchanged, and arrangements are being made for his readmission for reconstructive procedures on this hand

## DISCUSSION

The mechanism of para-articular ossification is not fully understood. A combination of diverse factors operating simultaneously is believed necessary

for the new-bone formation to occur. According to Déjérine, Ceillier, and Déjérine, who have contributed to the extensive literature on this subject, para-articular ossification is believed to be associated with the denervation of joints and with the absence of the physiological stimulus of motion, which in some way alters the para-articular tissues to favor calcification and later true ossification. The theories that have been advanced to explain these changes will not be discussed here since it is not the purpose of this paper to dwell on theoretical considerations.

In the case reported, it is thought that one or more of the following factors may have contributed to the ectopic-bone formation:

1. A period of severe debility accompanied by gross alterations in the peripheral circulation and acid-base balance;

2. A contusion of the cervical cord associated with transient quadriplegia;

3. Relative immobility of the elbow joints due to splinting on the armboard for intravenous feeding (right elbow) and positioning in flexion at the patient's side as a part of routine nursing care (left elbow);

4. Soft-tissue injuries to the elbows possibly incurred at the time of the original accident.

Removal of the ectopic bone should be delayed until such bone is fully mature in an effort to lessen the incidence of recurrence. Maturity usually occurs in a period of a year, and surgical excision should not be delayed to the point that structural changes take place within the joint itself. In the case reported, the excision of bone from each elbow was performed approximately one year after injury. There has been no recurrence of para-articular ossification in either elbow. On the contrary, muscle strength and the range of joint motion showed progressive improvement.

In the postoperative management of these elbows, we think that motion should be started at the earliest opportunity after soft-tissue reaction has had a chance to subside. In the case reported both elbows were mobilized on the tenth day after surgery with good results. It is important to emphasize that passive stretching of the elbow joint after operation is to be avoided.

## REFERENCES


1. Abramson, D. J., and Kamberg, Samuel: Spondylitis, Pathological Ossification, and Calcification Associated with Spinal-Cord Injury. J. Bone and Joint Surg., **31-A:** 275–283, Apr. 1949.
2. Brailsford, J. F.: Changes in Bones, Joints and Soft Tissues Associated with Disease or Injury of the Central Nervous System. British J. Radiol., **14:** 320–328, 1941.
3. Costello, F. V., and Brown, Austin: Myositis Ossificans Complicating Anterior Poliomyelitis. J. Bone and Joint Surg., **33-B:** 594–597, Nov. 1951.
4. Déjérine, Mme; Ceillier, A.; and Déjérine, Y.: Para-ostéo-arthropathies des paraplégiques par lésion médullaire. Étude anatomique et histologique. Rev. Neurol., **32:** 399–407, 1919.
5. Evans, E. B., and Smith, J. R.: Bone and Joint Changes Following Burns. A Roentgenographic Study—Preliminary Report. J. Bone and Joint Surg., **41-A:** 785–799, Jan. 1959.
6. Frejka, Bedřich: Heterotopic Ossification and Myositis Ossificans Progressiva. J. Bone and Joint Surg., **11:** 157–166, Jan. 1929.
7. Hess, W. E.: Myositis Ossificans Occurring in Poliomyelitis. Arch. Neurol. and Psychiat., **66:** 606–609, 1951.
8. Jeannopoulos, C. L.: To be published.
9. Johnson, J. T. H.: Atypical Myositis Ossificans. J. Bone and Joint Surg., **39-A:** 189–194, Jan. 1957.
10. Kolář, Jaromír, and Vrabec, Radko: Periarticular Soft-Tissue Changes as a Late Consequence of Burns. J. Bone and Joint Surg., **41-A:** 103–111, Jan. 1959.
11. Larsen, L. L., and Wright, H. H.: Para-Articular Ossification, a Complication of Anterior Poliomyelitis. A Case Report. Radiology, **69:** 103–105, 1957.
12. Miller, L. F., and O'Neill, C. J.: Myositis Ossificans in Paraplegics. J. Bone and Joint Surg., **31-A:** 283–294, Apr. 1949.
13. Shroyer, R. N.: Ossification of the Posterior Aspect of the Elbow. J. Bone and Joint Surg., **42-A:** 1156–1164, Oct. 1960.

# Sesamoid Bone of the Subscapularis Tendon

## Report of a Case

BY AVRUM FROIMSON, M.D., AND KARL S. ALFRED, M.D., CLEVELAND, OHIO

*From Saint Luke's Hospital, Cleveland*

To our knowledge a sesamoid bone in the region of the shoulder has not been previously reported. An article in the Italian literature discusses parasternal osseous nuclei in the vicinity of the costosternoclavicular articulations [5]; but there is no reference to a sesamoid of the shoulder in the available literature, even in exhaustive treatises on anatomy and skeletal roentgenography.

Fig. 1

Fig. 2

Fig. 1: Anteroposterior roentgenogram shows sesamoid bone overlying the humeral head.
Fig. 2: Oblique roentgenogram gives a profile view of the sesamoid bone.

### CASE REPORT

A white, male machinist, twenty-eight years old, was admitted to Saint Luke's Hospital on May 4, 1959, complaining of pain in his right shoulder. Two years before admission he tripped and fell at work, striking the front of his right shoulder on the concrete floor. He noted no deformity or disability after the accident, but thereafter he had constant aching in the anterior aspect of the right shoulder with occasional radiation of pain down the front of the arms as far as the elbow. His usual activities did not make the pain worse, but the pain increased in intensity when the arm was fully rotated externally. The shoulder hurt more at night, especially when the patient lay on it.

The general physical examination was entirely within normal limits. The only positive findings were in the right shoulder which appeared normal externally. Flexion, abduction, and active and passive rotation of the humerus were all limited by 15 degrees, as compared with movements of the left shoulder. The other movements of the shoulder were normal. An area of deep tenderness was found on the anterior aspect of the humeral head.

Routine laboratory investigations were within normal limits. The serum uric acid was 5.5 milligrams, the serum calcium was 11.6 milligrams, the serum phosphorus was 3.7 milligrams per 100 milliliters, and the alkaline phosphatase was 12.2 King-Armstrong units.

Roentgenograms (Figs. 1 and 2) of the right shoulder showed what was presumed to be a massive plaque of calcification in the rotator cuff anterior to the humeral head and slightly above the level of the tuberosities. Defects resembling fissures were visible in this plaque. The bones of the shoulder region appeared normal. Roentgenograms of the left shoulder revealed no abnormality.

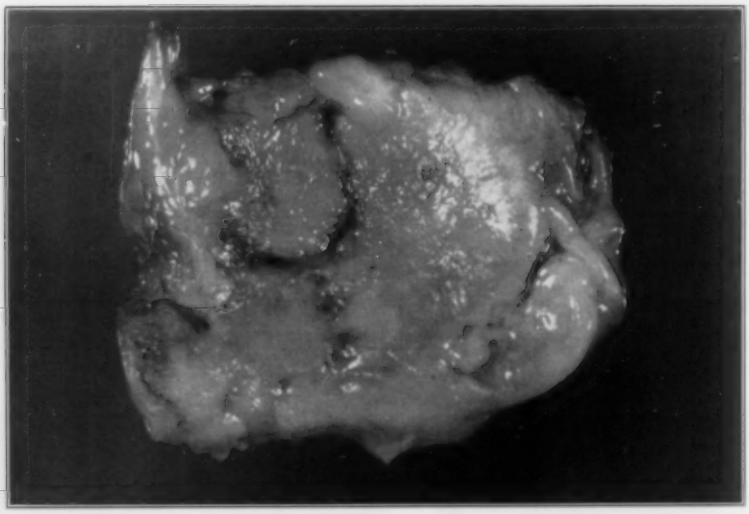


FIG. 3

Photograph of the articular surface of the sesamoid bone shows its tripartite structure.

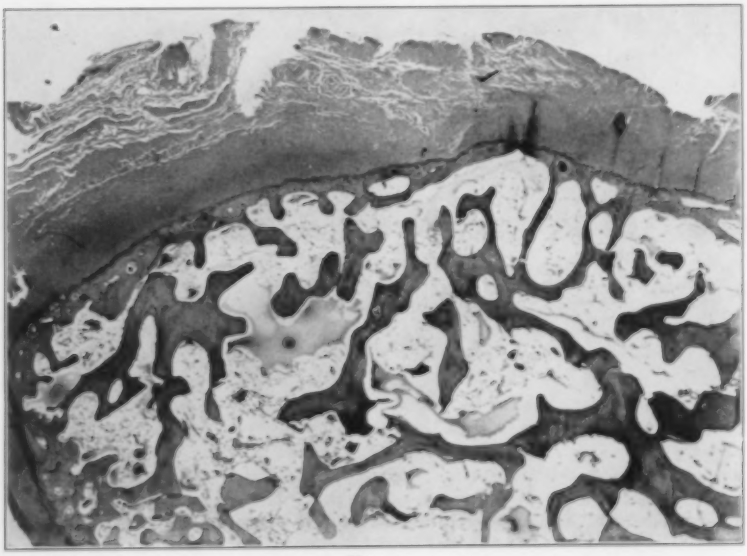


FIG. 4

Histological section shows dense bone covered by articular cartilage (× 17).

Surgical exploration of the right shoulder was performed under general anesthesia. The humeral head and tendinous cuff were exposed through an anterior deltoid incision. The coracoid process was osteotomized to uncover the tendon of the subscapularis muscle. Palpation outlined a large, hard mass occupying almost the entire subscapularis tendon near the humerus. The tendon was divided at its insertion, opening the shoulder joint. The bone mass was firmly attached to the inner fibers of the subscapularis tendon. It had a cartilaginous inner surface articulating with the head of the humerus, resembling the patella in shape, but slightly smaller. This sesamoid bone was tripartite, with one major and two minor sections. It was remote from the glenoid cavity. The anterior capsular attachment and the glenoid labrum were intact, as were the articular surfaces of the glenoid fossa and humeral head. By sharp dissection, the sesamoid bone was removed from

FIG. 5

High-power photomicrograph of the cartilaginous lining of the sesamoid bone (× 85).

the subscapularis tendon. The defect in the tendon was repaired by imbrication, and the shortened tendon was reattached to the severed distal stump. The coracoid process was replaced, and the wound closed in layers. A Velpeau dressing was used for four weeks after operation.

The gross specimen was a tripartite bone measuring 3.5 by 2.6 by 0.9 centimeter. On one surface there was adherent tendinous tissue; the other was covered by glistening tissue resembling articular cartilage (Fig. 3). Microscopically, the specimen consisted of mature cancellous bone covered on the concave surface by fibrillated articular cartilage (Figs. 4 and 5).

The patient was followed for eight months. He regained a full range of motion and normal strength except for loss of 20 degrees of external rotation. He remained free of pain.

## DISCUSSION

We believe that this sesamoid bone was a congenital anomaly found incidentally when attention was focused upon the shoulder by the patient's continuing complaint of pain. Unfortunately, there were no roentgenograms of the shoulder made at the time of the accident to substantiate this impression. Although it is possible that the tripartite structure of the bone may have been the result of an united fracture of the sesamoid caused by the patient's fall, it is thought more likely that his complaints were due to injury to the rotator cuff and abnormal mechanics of the glenohumeral joint related to the sesamoid bone.

Radiopaque densities are frequently seen in the shoulder cuff as areas of secondary calcification of degenerated tendon. These deposits may be well defined, round, oval, or striate, and, rarely, there may be calcification of the entire shoulder capsular apparatus. This process of calcification consists only in the deposition of cryptocrystalline hydroxyapatite, with the calcified foci exhibiting no evidence of osseous structure [4].

Sesamoid bones are distinct supernumerary bones located in tendon, ligament, or muscle [1]. Usually, they develop bilaterally, but they may be unilateral [1,4]. That they are of congenital origin and are not developed in response to adult stresses is evidenced by the presence of cartilaginous sesamoid nodules in the fetus in greater numbers than in the adult [2].

## REFERENCES

1. De Lorimier, A. A.; Moehring, H. G.; and Hannan, J. R.: Clinical Roentgenology. Vol. 1, p. 29. Springfield, Illinois, Charles C. Thomas, 1954.
2. Gray, Henry: Anatomy of the Human Body. Ed. 26, pp. 313–314. Edited by C. M. Goss. Philadelphia, Lea and Febiger, 1954.
3. Joseph, J.: The Sesamoid Bones of the Hand and the Time of Fusion of the Epiphyses of the Thumb. J. Anat., **85**: 230–241, 1951.
4. Köhler, Alban: Borderlands of the Normal and Early Pathologic in Skeletal Roentgenology. Ed. 10, p. 151. Revised by E. A. Zimmer and translated by J. T. Case. New York, Grune and Stratton, 1956.
5. Motto, A., and Nai Fovino, G.: I nuclei ossei parasternali; considerazioni radiologiche e cliniche. Minerva Ortop., **9**: 391–396, 1958.

# Motor Paralysis of the Extremities in Herpes Zoster*

BY B. DAVID GRANT, M.B., F.R.C.S. (EDIN.), AND
CARTER R. ROWE, M.D., BOSTON, MASSACHUSETTS

*From the Massachusetts General Hospital, Boston*

Herpes zoster, an ancient disease of man recognized since the time of Celsus, is well known as a benign viral infection affecting the sensory nerves. That this disease may also cause paralysis is less well known. It is our purpose to review the experience with this disease at the Massachusetts General Hospital over a ten-year period.

Our interest in paralytic involvement in herpes zoster was stimulated by a patient (Case 5) sent to one of us (C.R.R.) because of severe pain in the right lower extremity, in whom there subsequently developed a typical herpetic rash followed shortly thereafter by a rapidly progressive paralysis of the right quadriceps with loss of the knee and ankle reflexes. This definite motor involvement complicating herpes zoster led us to review the literature and the case records of patients with this disease who were admitted to our hospital over a ten-year period.

## HISTORICAL REVIEW OF MOTOR PARALYSIS

William Broadbent reported motor involvement of the upper extremity due to herpes zoster in 1866. Ten years later, Hardy published the first account of lower-limb involvement.

Up to the time of writing forty-two cases of extremity paralysis due to herpes zoster have been recorded, thirty involving the upper extremity and twelve the lower. In addition, there have been many reports of motor involvement of the trigeminal and facial nerves [15], and of paralysis of the intercostal and adbominal muscles [26,28,36], as well as one instance of diaphragmatic paralysis [12].

The degree of recovery from herpes motor paralysis, as reported in the literature, is variable [6,7,13,16,23,29,31]. Taterka and O'Sullivan claimed that only 16 per cent of patients recover completely, and that the time required for recovery was from six months to one year.

## PATIENTS STUDIED IN THIS REPORT

This study includes patients with a diagnosis of herpes zoster who were admitted to the Massachusetts General Hospital because of this disease or in whom symptoms developed while they were under treatment for another condition (Table I). The study covers a ten-year period from 1948 to 1958. There were 101 patients, fifteen with involvement of the upper and nine with involvement of the lower extremities. Of the twenty-four patients with the disease involving the extremities, five (21 per cent) had motor paralysis—two in the upper and three in the lower extremities. Only one patient, with paralysis of the upper extremity, was left with residual paralysis.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Miami Beach, Florida, January 12, 1961.

As seen in Chart I, the disease occurred in elderly people primarily. There were sixty-four women and thirty-seven men in the whole series.

## CASE REPORTS

Case 1. E.L., a woman, seventy-three years old, was admitted to the hospital on February 5, 1957, five weeks after onset of pain in her right shoulder and the lateral aspect of the arm, extending down to the thumb, index, and long fingers. The diagnosis on admission was a suspected cervical-cord tumor. Four days after the onset of pain, vesicles appeared on the shoulder, the front and back of the arm, and the volar aspect of the forearm. Ten days later she could no longer abduct, flex, or adduct her right shoulder. Three days before admission she had noted tingling and numbness in the tips of the right thumb and index and long fingers. She had been in good health except for intermittent pain in her right shoulder. The patient could not recall having had varicella.

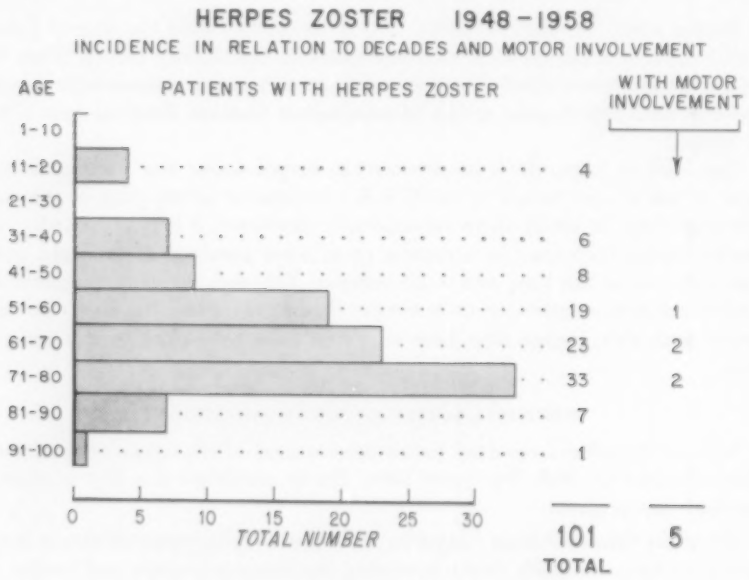



Chart I

Examination showed a herpetic rash on the lateral aspect of the patient's right shoulder and volar aspect of the right forearm. Tenderness was present over the right side of the neck and right shoulder. There was almost complete paralysis of the right deltoid, weakness of the biceps and triceps, and probably weakness of other muscles, but these could not be tested satisfactorily because of pain. Hypesthesia was found in the fourth, fifth, sixth, and seventh cervical dermatomes (Fig. 1). The biceps, triceps, and supinator reflexes were absent on the right and normal on the left. Neck motions were free and without pain; the cranial nerves were normal. The results of routine laboratory examinations were within normal limits. Roentgenograms showed mild osteo-arthritic changes in the shoulder joint, marked degenerative changes in the mid-cervical spine, and no evidence of metastatic disease in the skeleton. Exercises were commenced and, on February 20, 1957, when the acute symptoms had subsided, the patient was discharged. She was seen again two weeks after discharge and had a definite return of power in all involved muscle groups, but the deltoid could be rated no better than *poor*.

She was subsequently followed by her family doctor and was not seen again until August 1960, three and a half years after onset. She said that she had had difficulty raising her arm properly for nine months after the onset of paralysis, but thereafter had no trouble. Examination showed a normal range of active motion in both shoulders; no sensory loss; normal muscle power in the right deltoid, biceps, and triceps; and equal strength of grip. The biceps, triceps, and supinator reflexes were brisk and equal in both upper extremities.

Case 2. A.M., a woman, fifty-five years old, first noted, on August 7, 1957, tingling and ache in the left upper chest and on the anteromedial aspect of the left arm. On August 11, a vesicular

eruption appeared on the lateral aspect of her arm and forearm, which began to clear about two days later. The patient then noticed that her fingers were numb and, about twelve days after onset of the eruption, she found that her hand was "paralyzed", with weakness of her wrist, fingers, and

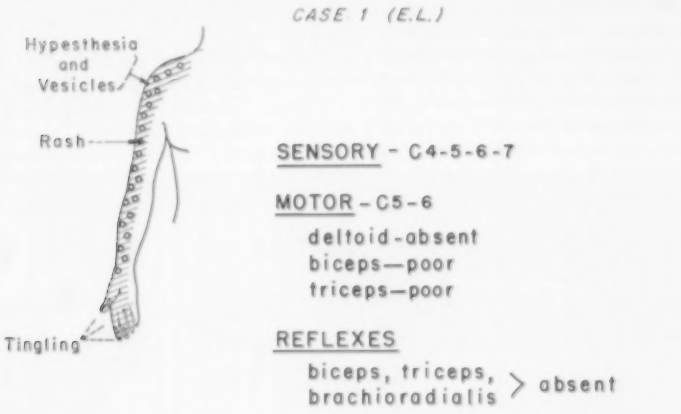



FIG. 1

Case 1. E.L., a woman, seventy-three years old.

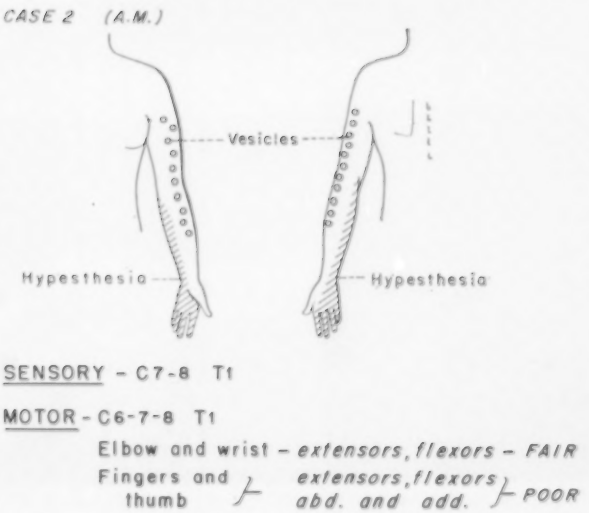

CASE 2 (A.M.)
Vesicles
Hypesthesia
Hypesthesia
SENSORY - C7-8 T1
MOTOR - C6-7-8 T1
Elbow and wrist - extensors, flexors - FAIR
Fingers and thumb - extensors, flexors abd. and add. - POOR
REFLEXES - Biceps and triceps - DEPRESSED
Follow-up 3yrs. Residual motor paralysis of hand

FIG. 2-A

Case 2. A.M., a woman, fifty-five years old.

thumb. On admission, on September 19, 1957, examination of the left upper extremity showed marked weakness of the flexors, extensors, abductors, and adductors of the fingers and thumb. Moderate weakness of the flexors and extensors of the wrist and of elbow extension was found with limitation of motion of the fingers. There was redness, dryness, and scaling of the skin of the palm,

and slight diminution of the left biceps and marked diminution of the left triceps reflexes (Fig. 2-A). A diagnosis was made of herpes zoster involving the sixth, seventh, and eighth cervical and first thoracic nerves on the left with post-herpetic neuralgia and secondary stiffness of the fingers. Routine laboratory examinations were within normal limits. An electromyogram using a concentric needle electrode showed fibrillations of denervation in the extensor carpi radialis, flexor carpi ulnaris, and opponens muscles. On attempted voluntary contraction action potentials were present in these areas, but reduced in voltage and frequency. The abductor digiti quinti was not tested because of muscle sensitivity. The electromyogram was interpreted as showing incomplete degeneration of the motor component of the spinal nerves implicated clinically. Exercises were prescribed and the patient was discharged to the care of her family doctor. She subsequently was treated at another hospital where, after several novocain blocks, which gave temporary relief of pain, a sympathectomy was performed in October 1957. This helped "the circulation", but did not improve the power of her hand or her sensation.

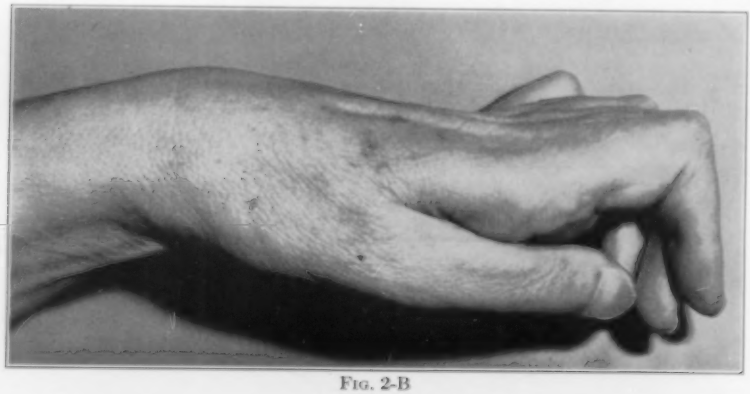


FIG. 2-B

FIG. 2-C

Figs. 2-B and 2-C: Claw-hand deformity and atrophy resulting from partial residual intrinsic-muscle deformity.

At follow-up examination, three years later on August 27, 1960, the patient stated that the weakness in her wrist and elbow had improved, but that her hand was still deformed, with persistent numbness of the palm (Figs. 2-B, 2-C, and 2-D). Examination revealed one-half inch of wasting of the left arm and forearm, a claw-hand deformity on the left, with no abduction or adduction of her thumb, and stiffness of all the interphalangeal joints of thumb and fingers. In the thumb, flexion power was rated *fair plus* and extensor power *fair minus;* circumduction could be carried out, but rather poorly. In the fingers, the extensors were rated *fair minus.* Although joint contractures made accurate assessment of muscle power difficult, the forearm muscles, the triceps and biceps, and the deltoid were rated *good.* The triceps and biceps reflexes were present and equal. An

area of hypesthesia was present on the palm. The radial nerve seemed to be essentially unaffected. An electromyogram of the opponens muscle showed giant action potentials during attempted voluntary motion. This was interpreted as early regeneration. Voluntary movement of the first and second dorsal interosseus muscles produced interference patterns with lower voltage than the normal, which were also intrepreted as showing beginning regeneration. In the abductor digit quinti, denervation fibrillations were present in addition to discrete diphasic discharges and occasional giant action potentials. The interference pattern in this muscle was better than that in some of the others supplied by the ulnar nerve. These findings were interpreted as indicating beginning regeneration of both the median and the ulnar nerves. Direct electrical stimulation revealed a chronaxy of ten milliseconds, but some tendency toward a tetanic response at this duration of impulse in the muscles innervated by both the median and ulnar nerves.

FIG. 2-D
Area of residual numbness in the palm.

CASE 3. R.B., a man, seventy-three years old, was admitted on March 31, 1950, six weeks after onset of severe burning pain down the back of the right lower extremity, followed within a few days by skin vesicles in the same distribution. He had never had pain in the back or the sciatic region before and had been in good health. Examination showed remnants of a herpetic rash on the right buttock and the back of the right thigh, marked weakness of the right hamstrings, absence of the right ankle reflex, and marked hypesthesia on the dorsal and plantar aspects of the right foot (Fig. 3). Routine laboratory studies were within normal limits. Roentgenograms showed no evidence of metastatic bone disease in the skeleton, and gastro-intestinal roentgenograms were within normal limits. The patient was discharged from the hospital on April 8, 1950. Six weeks later his pain was much improved, but the ankle reflex was still absent.

When seen at follow-up on January 5, 1959, the patient still complained of discomfort in the right leg described as "like fibers running down my leg". Examination showed mild hypesthesia on the dorsal and plantar aspects of the right foot and one-half inch of wasting of the right calf. Knee and ankle reflexes were present and equal. There was no demonstrable weakness in the hamstring muscles.

CASE 4. E.M., a woman, sixty-nine years old, was admitted to the Massachusetts General Hospital on March 27, 1951, with a provisional diagnosis of a cerebral vascular accident twelve weeks after the onset of sudden severe pain in the right lower extremity, radiating into the calf and dorsum of the foot.

She had been admitted to another hospital two months previously shortly after onset of pain, and an initial diagnosis of thrombophlebitis had been made. One week later, however, a herpetic rash had appeared on the lateral side of the leg and on the dorsum of the foot. Although the rash had cleared, severe pain radiating from the region of the right hip down the posterolateral aspect of the leg to the toes had continued and foot-drop had developed in this extremity.

When she was transferred to the Massachusetts General Hospital, examination showed herpetic scars on the sole of the right foot, hyperesthesia over the distribution of the fifth lumbar and first sacral dermatomes, and weakness of dorsiflexion of the right ankle and toes. Straight-leg raising was 90 degrees bilaterally. Knee reflexes were equal; the ankle reflex was absent on the right and present on the left (Fig. 4). Routine laboratory studies were within normal limits. Lumbar puncture

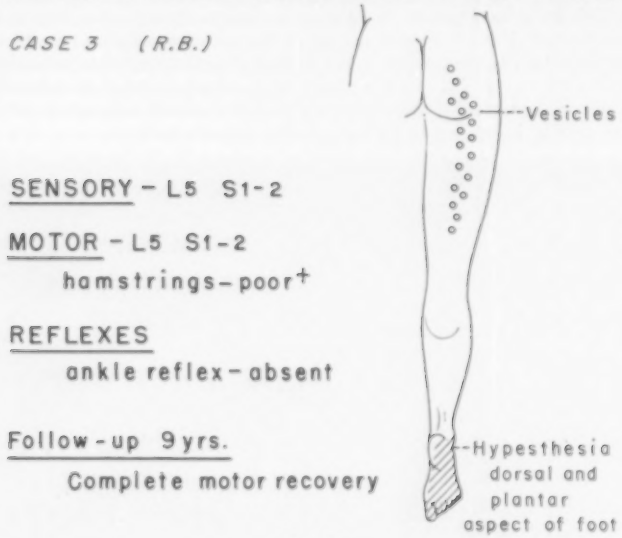



FIG. 3

Case 3. R.B., a man, seventy-three years old.

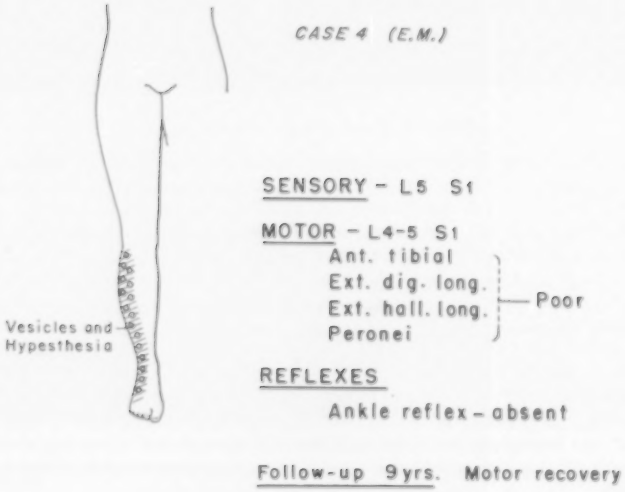



FIG. 4

Case 4. E.M., a woman, sixty-nine years old.

showed a total protein of fifty-four milligrams per 100 milliliters. Roentgenograms of the lumbosacral spine showed slight hypertrophic lipping on the left superior margins of the body of the fourth lumbar vertebra. A myelogram was normal. On April 5, 1951, slight voluntary motion was noted in the right foot. Electrical testing of the tibialis anterior, toe extensors, and peroneals revealed a complete reaction of degeneration without reversal of polarity. An electromyogram of these muscles showed some action potentials on attempted voluntary contraction. The patient was discharged on April 10, 1951.

At follow-up in September 1960 the patient still had weakness in the foot and knee and walked with a cane. The right foot and toes were still numb and there was a sensation in the foot described "as if it were waking up". Her foot felt "tight" and it was difficult to move the foot and toes. Physical examination revealed hypesthesia of the right lower lateral calf and dorsum of the foot and diffuse muscle weakness below the knee on the right (extensor hallucis longus, *fair;* tibialis anterior, *fair plus;* extensor digitorum longus, *fair;* peroneals, *fair;* tibialis posterior, *poor;* gastrocnemius, *poor;* flexor hallucis longus, *poor;* and flexor digitorum longus, *poor*). Knee reflexes were present and equal. The left ankle reflex was normal; the right was depressed. She walked with a drop-foot gait on the right. Electromyographic studies now showed normal electrical reactions.

Case 5. S.M., a man, seventy years old, was seen on November 12, 1957, six days after the onset of pain radiating down the anterior and lateral aspects of the right thigh (Fig. 5-A). The pain, which was described as "like a bad bruise", did not extend below the knee and was not related to a particular motion or position. There were no back symptoms. The patient walked with a mild right limp. Sensation of the lower extremity was normal. There was no evidence of muscle weakness.

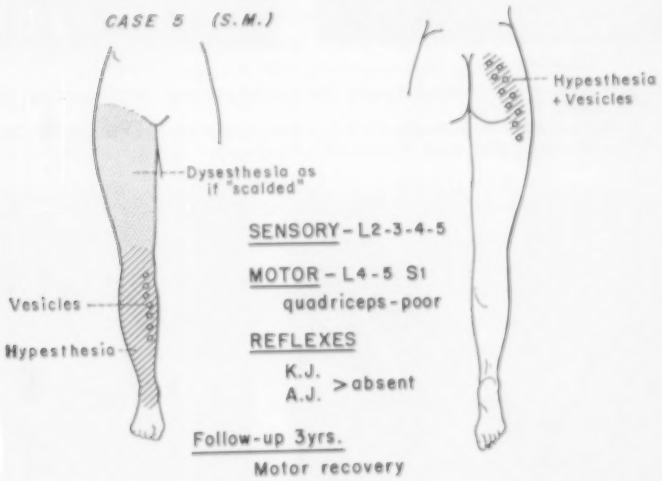



Fig. 5-A

Case 5. S.M., a man, seventy years old.

Straight-leg raising was normal. On November 19, shingles appeared on the right buttock and upper part of the thigh, as well as along the medial aspect of the leg to the ankle (Fig. 5-B). Some muscle twitching could be seen in the right quadriceps and the right knee reflex was absent. Approximately four weeks after onset of the pain the patient noted weakness of his right lower extremity and said he had fallen several times. The pain was continuous down his thigh which, at times, felt numb and cold. Examination now showed marked weakness and atrophy of his quadriceps (Fig. 5-C) and hypesthesia on the anterior and lateral aspects of the leg, with some hyperesthesia over the anterior aspect of the thigh. The knee and ankle reflexes were absent on the right and present and normal on the left. When the patient was admitted to the hospital it was found that he had some weakness of hip flexion, as well as of knee extension. During hospitalization weakness and atrophy of his quadriceps progressed. The routine laboratory tests and the serum proteins were within normal limits. The acid phosphatase was 2.2 Bodansky units; the alkaline phosphatase 6.8 Bodansky units. The spinal fluid showed a protein of eighty-four milligrams per 100 milliliters, 161 red blood cells, and six lymphocytes. The gold sol curve was 1123432111. Roentgenograms of the lumbar spine and sacral region were normal, as was a myelogram. Electromyograms of the right quadriceps showed no clear-cut action potentials on attempted voluntary contraction, and no definite fibrillation potentials were seen. On electrical stimulation of the quadriceps, the rheobase was too high to be measured. When the electrodiagnostic tests were repeated three days later, they showed the electrical threshold of the rectus femoris and the vastus medialis to be so high that a visible response could not be obtained within the patient's pain tolerance. A normal chronaxy was found in the vastus lateralis. The electromyogram of the rectus femoris and vastus medialis showed electrical silence at rest and a very low voltage interference pattern on voluntary contraction. The vastus lateralis

FIG. 5-B

FIG. 5-C

Fig. 5-B: The vesicles over the right buttocks. The vesicles extended down the upper part of the thigh and medial aspect of the leg.

Fig. 5-C: Marked weakness and atrophy of the patient's quadriceps muscle group. This photograph was made four weeks after onset of pain, three weeks after the appearance of the vesicles.

FIG. 5-D

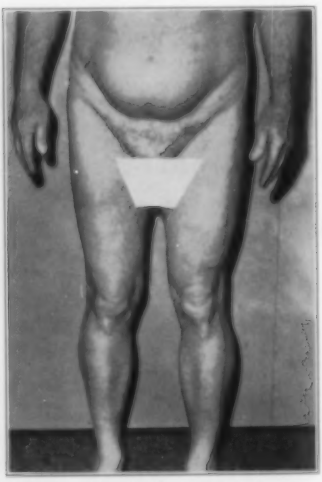


FIG. 5-E

Fig. 5-D: Four months after the vesicular rash. The right quadriceps was now rated *fair plus*.

Fig. 5-E: Five years after onset of herpes zoster involving the right lower extremity. All this time the quadriceps was rated *good*, although slight atrophy of the muscle still persisted.

showed no fibrillation potentials and a normal interference pattern on voluntary contraction. The tests were consistent with either primary muscle disease or severe atrophy secondary to femoral-nerve degeneration. The patient was discharged on December 14, 1957. On January 8, 1958, the right ankle reflex was found to have returned, but the right knee reflex was still absent. There was less atrophy of the right thigh and the gluteal region. Hypesthesia persisted over the same area as previously noted, but it was not quite so marked. Stretching the right femoral nerve was still painful. On March 6, 1958, the patient still had hypesthesia over the front of the right knee; he still did not trust his leg on going down stairs, although it no longer gave way. He stated that the leg "felt as though it were wrapped in a tight bandage". The right quadriceps was now rated *fair plus* (Fig. 5-D). The right knee reflex was still absent. On December 4, 1958, electrodiagnostic tests were performed on the right quadriceps, tibialis anterior, toe extensors, and peroneals. Direct electrical stimulation of these muscles showed a normal rheobase and a chronaxy of 0.5. The electromyogram of these muscles revealed no fibrillations of degeneration and a normal-appearing interference

pattern on voluntary effort. Thus there remained no electrical residual which could be quantitated.

At follow-up examination on October 28, 1960, three years after onset of herpes zoster, the patient stated that his right lower extremity was "almost normal". Physical examination disclosed slight weakness of the right quadriceps which was rated *good* (Fig. 5-E), marked depression of the right knee reflex, a persistent area of paresthesia over the anterior aspect of the knee, and one-quarter inch of wasting of the right quadriceps. He was considered to have regained full function.

## PATHOLOGY

Herpes zoster is now generally agreed to be a viral infection affecting the posterior root ganglia and skin. Wilson suggested that the organism enters through the nasal mucosa and is carried by the blood stream to the posterior root ganglia and thence along a sensory nerve to the skin. This does not explain why only one or two spinal segments may be affected. Others [20,21,22] believe that the virus enters through the nerve fibers or perineural lymphatics. This presupposes, as Wilson pointed out, the unlikely sequel of the infection returning from the posterior root ganglia to the skin vesicles.

Von Bärensprung, in 1861, first showed that herpes zoster was a disease of the nervous system with changes in the posterior root ganglia. Head and Campbell, in 1900, demonstrated that herpes zoster produces a typical inflammatory reaction with round-cell infiltration and hemorrhages in the posterior root ganglia and secondary changes in the posterior nerve roots and posterior columns similar to those following experimental section of the posterior root.

These workers noted the striking similarity of the histological changes in herpes zoster and acute anterior poliomyelitis. More recent work, however, showed that the inflammation involves the posterior root ganglion, the posterior root, and posterior horn, the pars intermedia, and the anterior horn extending up and down the cord for a variable distance [10,11,17,18].

Adams described four different histological changes that distinguish herpes zoster from other pathological conditions:

1. Ganglionitis marked by necrosis of all or part of the ganglion with or without hemorrhage and surrounded by an intense lymphocytic infiltration;

2. Poliomyelitis resembling anterior poliomyelitis but readily distinguished by its unilaterality, segmental localization, and greater involvement of the posterior horn, root, and spinal ganglion;

3. Leptomeningitis in which the cellular infiltrate is relatively slight and limited principally to the involved spinal segments and the nerve roots;

4. Peripheral mononeuritis seen not only in the nerves distal to the involved ganglion, but also in the anterior root both within the meninges and in the extrathecal portion of the roots contiguous to the involved spinal ganglia.

Herpes zoster has long been linked to varicella. Both Brain and Amies showed a serological relationship between the two viruses. Rake and his associates showed the similarity of the two viruses by electron-microscope studies. More recently, Weller and his associates demonstrated by both cultural and serological studies that herpes zoster and varicella are caused by the same virus.

## DISCUSSION

Motor paralysis in the limbs is rare in herpes zoster; reports of only forty-two cases were published in the past ninety-four years. It must be carefully differentiated from other diseases. All five of our patients with motor involvement undoubtedly had herpes zoster with the characteristic vesicular rash confined to a dermatome.

Tumors of the spinal cord were considered so strongly in some of our patients that myelograms were made even though a herpetic rash was clearly visible and

distributed over the same segments as the motor palsy. All the myelograms were normal.

In all our patients the motor paralysis and the dermatome distribution of the herpetic rash corresponded to approximately the same spinal segment. Taterka and O'Sullivan observed this relationship in 90 per cent of the patients, with the rash and palsy always on the same side. Kendall, however, noted that the anatomical relationships of the eruption, the paralysis, and the rash are by no means constant. Frequently these do not coincide, as was the case in three of the five cases of lower motor neuron involvement that he reported. One of his patients showed a rash over the seventh and eighth cervical and first thoracic dermatomes on the left, and motor loss of the third, fourth, fifth, and sixth cervical dermatomes on the right, with complete anesthesia of the sixth and seventh cervical segments.

TABLE I

INVOLVEMENT OF THE EXTREMITIES IN 101 PATIENTS WITH HERPES ZOSTER

| Extremity | No. of Involvements | With Motor Paralysis | Recovered | With Residual Paralysis |
|---|---|---|---|---|
| Upper | 15 | 2 | 1 | 1 |
| Lower | 9 | 3 | 3 | 0 |
| Totals | 24 | 5 | 4 | 1 |

Abercrombie also reported a patient in whom there was motor involvement of the fourth and fifth lumbar dermatomes, sensory loss of the first and second sacral dermatomes, and the original herpetic rash distributed in the third sacral dermatome.

From the literature it would appear that recovery from paralysis to a functional level occurred in about 75 per cent of the cases reported. In our own five patients, three had excellent functional recovery, although one (Case 5) still had a marked depression of the knee reflex three years after onset. The other two (Cases 2 and 4) still had considerable residual disability three and nine years, respectively, after onset. Case 2 had definite residual paralysis as shown by both physical examination and electromyogram. Case 4, nine years after her initial illness, had no clinical improvement in muscle power, but the electromyogram, which initially showed a complete degeneration, now showed a normal pattern suggestive of complete motor recovery. We may speculate that this is some form of protective mechanism and perhaps allied to some of the severe forms of post-herpetic neuralgia which do not respond to such extreme treatment as skin ablation of the affected dermatome or posterior rhizotomy.

Herpes zoster has long been known to be related to varicella. Cheatham suggested that varicella is the result of hematogenous spread of the virus in non-immune individuals and that herpes zoster results from a neurogenous spread in a person with humoral immunity. None of our patients recalled any exposure to varicella or herpes zoster, and exposure of this sort was unusual in the cases of motor paralysis reported in the literature. Cheatham and his associates reported their findings at autopsy of a patient who died of varicella. They found a typical zosteriform eruption in addition to the disseminated varicella lesions, intranuclear inclusions in the thoracic-root ganglion of the affected dermatome, as well as in three other ganglia. They also found these inclusions in the nerve cells of the myenteric plexus of the small intestine. They suggested that the simultaneous involvement of the thoracic-root ganglia and myenteric plexus could be consistent with a neurogenic spread of the virus. This would not explain why the virus is so

selective in its attack, affecting, as a rule, solitary or adjoining dermatomes only. It is possible that the virus remains dormant, in the carrier state, in the nervous system, probably in the posterior root ganglion, to be activated by unknown causes and then pass down the nerve to produce the typical skin eruption. The causes of activation presumably include trauma, neoplasm, and neurological disease. This would explain so-called symptomatic herpes zoster which is periodically seen complicating cord and vertebral lesions. Worster-Drought and McMenemey advised that one should always bear in mind the possibility that herpes zoster may be symptomatic of underlying disease of the central nervous system. In two patients reviewed by us at our hospital herpes zoster of the ninth thoracic dermatome developed after a crush fracture of the body of the ninth thoracic vertebra. Eleven per cent of the 101 patients in our series had malignant neoplasms. This is, of course, a high incidence and can be attributed to the fact that this was a select series since the patients studied were in a hospital. As a general rule patients with herpes zoster are not hospitalized. We found that herpes zoster is most common in the decades when malignant tumors are most frequent. We consider that this is probably an incidental relationship.

As the result of this study we would suggest that perhaps if we examined patients with herpes zoster more carefully we might find clinical and subclinical weakness more frequently. Although the initial physical signs may be alarming, the general prognosis may be considered good.

## SUMMARY

1. One hundred and one patients with herpes zoster were reviewed in relation to motor paralysis of the extremities.

2. Motor paralysis was found in five patients; two had involvement of the upper limb and three of the lower limb.

3. One patient had residual motor paralysis.

4. As seen from our study and from a review of the literature, the prognosis for motor paralysis in herpes zoster is good in the majority of patients.

5. The pathology of the disease is discussed and its close relationship with varicella is noted.

## REFERENCES

1. Abercrombie, R.G.: Herpes Zoster with Muscular Paralysis and Disturbance of Sensation. British Med. J., **1**: 778, 1941.
2. Adams, R.D.: The Pathological Features of Herpes Zoster. Bull. New England Med. Cent., **6**: 12–16, 1944.
3. Amies, C.R.: The Elementary Bodies of Zoster and Their Serological Relationship to Those of Varicella. British J. Exper. Pathol., **15**: 314–320, 1934.
4. von Bärensprung: Cited by Head and Campbell[14].
5. Brain, R.T.: The Relationship between the Viruses of Zoster and Varicella as Demonstrated by the Complement-Fixation Reaction. British J. Exper. Pathol., **14**: 67–73, 1933.
6. Broadbent, W.H.: Case of Herpetic Eruption in the Course of Branches of the Brachial Plexus, Followed by Partial Paralysis in Corresponding Motor Nerves. British Med. J., **2**: 240, 1866.
7. Carter, A.B., and Dunlop, J.B.W.: Paresis Following Herpes Zoster. A Report of Two Cases. British Med. J., **1**: 234–235, 1941.
8. Cheatham, W.J.: The Relation of Heretofore Unreported Lesions to Pathogenesis of Herpes Zoster. Am. J. Pathol., **29**: 401–412, 1953.
9. Cheatham, W.J.; Weller, T.H.; Dolan, T.F., Jr.; and Dower, J.C.: Varicella: Report of Two Fatal Cases with Necropsy, Virus Isolation, and Serologic Studies. Am. J. Pathol., **32**: 1015–1028, 1956.
10. Denny-Brown, D.; Adams, R.D.; and Fitzgerald, P.J.: Pathologic Features of Herpes Zoster. A Note on "Geniculate Herpes". Arch. Neurol. and Psychiat., **51**: 216–231, 1944.
11. Faure-Beaulieu, and Lhermitte, Jean: Les lésions médullaires du zona idiopathique. La myélite zostérienne. Rev. Neurol., **1**: 1250–1258, 1929.
12. Halpern, S.L., and Covner, A.H.: Motor Manifestations of Herpes Zoster. Report of a Case of Associated Permanent Paralysis of the Phrenic Nerve. Arch. Int. Med., **84**: 907–916, 1949.
13. Hardy, M.: Du zona. Gaz. d. Hôp., **48**: 827–828, 1876.

14. Head, Henry, and Campbell, A.W.: The Pathology of Herpes Zoster and Its Bearing on Sensory Localisation. Brain, **23:** 353–523, 1900.
15. Hunt, J.R.: On Herpetic Inflammations of the Geniculate Ganglion. A New Syndrome and Its Complications. J. Nerv. and Ment. Dis., **34:** 73–96, 1907.
16. Kendall, David: Motor Complications of Herpes Zoster. British Med. J., **2:** 616–618, 1957.
17. Lhermitte, J., and Nicolas: Les lésions du Zona. La myélite zostérienne. Rev. Neurol., **40:** 361–364, 1924.
18. Lhermitte, Jean, and Vermés: Les lésions dy système nerveux centrale dans le zona. Rev. Neurol., **1:** 1231–1236, 1930.
19. McIntyre, J.H.: Herpes Zoster with Involvement of Anterior Horn Cells. British Med. J., **2:** 716–717, 1951.
20. Marinesco, G., and Draganesco, S.: Contribution à la pathogénie et à la physiologie pathologique du zona zoster. Rev. Neurol., **39:** 30–45, 1923.
21. Marinesco, G., and Draganesco, St.: Nouvelles contributions à la pathogénie et à la physiologie pathologique du zona zoster. Presse Méd., **35:** 1025–1028, 1927.
22. Montgomery, D.W.: Herpes Zoster as a Primary Ascending Neuritis. Arch. Dermatol. and Syphilol., **4:** 812–817, 1921.
23. Parkinson, Thomas: Rarer Manifestations of Herpes Zoster. A Report on Three Cases. British Med. J., **1:** 8–10, 1948.
24. Rake, Geoffrey; Blank, Harvey; Coriell, L.L.; Magler, F.P.O.; and Scott, T.F.McN.: The Relationship of Varicella and Herpes Zoster: Electron Microscope Studies. J. Bacteriol., **56:** 293–303, 1948.
25. Scobey, R.R.: Acute Anterior and Acute Posterior Poliomyelitis: Are They the Same Disease? Arch. Pediat., **66:** 402–410, 1949.
26. Söderbergh, Gotthard: Syndromes moteurs de l'abdomen en présence de zona intercostal. Acta Med. Scandinavica, **54:** 170–182, 1920.
27. Taterka, J.H., and O'Sullivan, M.E.: The Motor Complications of Herpes Zoster. J. Am. Med. Assn., **122:** 737–739, 1943.
28. Taylor, Frederick: A Case of Shingles Followed by Paralysis of the Abdominal Muscles. Guy's Hosp. Rep., **52:** 37–42, 1895.
29. Tudor, R.B.: Herpes Zoster with Motor Involvement. Journal-Lancet, **71:** 184, 1951.
30. Vernon, B J.: Five Cases of Herpes Opthalmicus. St. Bartholomew's Hosp. Rep., **4:** 121–128, 1868.
31. Waller, G.: Two Cases of Herpes with Motor Paralysis. British Med. J., **2:** 560, 1885.
32. Weller, T.H., and Witton, H.M.: The Etiologic Agents of Varicella and Herpes Zoster. Serologic Studies with the Viruses as Propagated *in Vitro*. J. Exper. Med., **108:** 869–889, 1958.
33. Weller, T.H.; Witton, H.M.; and Bell, E.J.: The Etiologic Agents of Varicella and Herpes Zoster. Isolation, Propagation, and Cultural Characteristics *in Vitro*. J. Exper. Med., **108:** 843–868, 1958.
34. Wilson, S.A.K.: Neurology. Vol. 1, p. 672. London, Edward Arnold and Co., 1940.
35. Worster-Drought, C., and McMenemey, W.H.: Paresis of Upper Motor Neurone Type Following Herpes Zoster. J. Neurol. and Psychopathol., **14:** 52–56, 1933.
36. Wright, A.D.: Herpes Zoster involving Left Quadratus Lumborum and ObliqueMuscles,with Complete Reaction of Degeneration. Lumbar Pseudo-Hernia in Region of Scars. Proc. Roy. Soc. Med., **25:** 1116, 1932.

# Polyostotic Fibrous Dysplasia Associated with Hyperthyroidism

BY JOHN P. KIM, M.D., AND SHAMSHER A. K. KHERA, M.B., B.S.,
REGINA, SASKATCHEWAN, CANADA

*From the Services of Orthopaedics and Paediatrics, Regina General Hospital, Regina*

Albright and associates [1] described a syndrome characterized by osteitis fibrosa disseminata, abnormal pigmentation, and precocious puberty in female patients. In 1938, Lichtenstein reviewed in detail eight cases of widespread fibrous dysplasia of bone and attempted to show that this condition formed a definite disease entity and suggested use of the term *polyostotic fibrous dysplasia* because bone lesions constituted the essential feature of the disease.

Jaffe and Lichtenstein further reviewed ninety cases of fibrous dysplasia of bone, varying from mild monostotic to severe polyostotic involvement with or

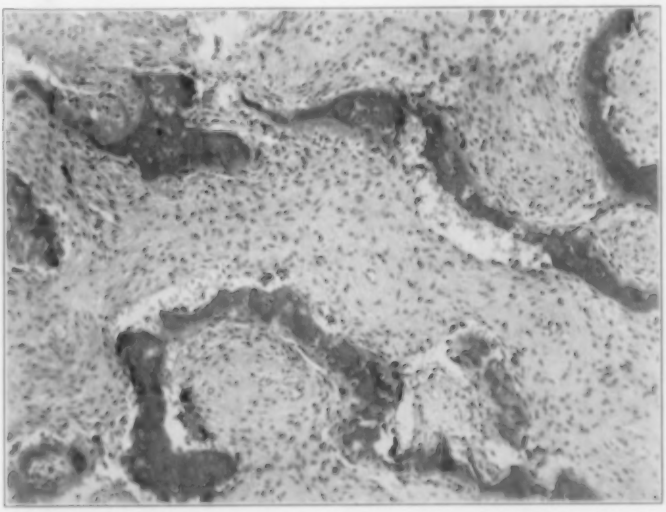


FIG. 1

Microscopic section from the subtrochanteric region of the left femur, showing irregular spicules of bone embedded in fibrous tissue.

without endocrinal dysfunction, and they suggested that those skeletal lesions were manifestations of one basic pathological condition. During the past two decades a number of authors extensively reviewed this subject [2,3,5,7,8,16,18,21,22].

One or more of the endocrinal disturbances often associated with polyostotic fibrous dysplasia include sexual precocity in female patients, accelerated skeletal growth and maturation, acromegaly, hyperthyroidism, diabetes mellitus, hypoplastic adrenal glands, hyperpituitarism, and gynecomastia. A basophilic adenoma of the anterior pituitary gland was found in a patient at autopsy [18]. The common endocrinal dysfunction is the accelerated skeletal growth and maturation and precocious puberty in female patients, but four cases of sexual precocity were also reported in male patients [7,13,22].

Thyroid dysfunction is the third commonest manifestation of associated

endocrinal abnormalities. About 5 per cent of the patients have been reported to have hyperthyroidism [23]. Yettra and Starr reviewed all cases of polyostotic fibrous dysplasia with thyroid dysfunction and found four cases in which hyperthyroidism was unquestionable [23]. They added their two cases to record a total of six. One more case was reported by Lagèze and associates in 1955. Hyperfunction of the thyroid was suspected in eight more patients with this disease [4,6,7,9,11,19,20].

FIG. 2

FIG. 3

Fig. 2: Roentgenogram of the left femur (December 13, 1955) shows a subtrochanteric transverse fracture through the distal margin of an area previously reinforced with a bone graft. This fracture occurred when the patient fell down. The intertrochanteric region shows rarefaction, indicating early recurrence of the disease or absorption of the graft of homogenous bone. The entire shaft is involved.

Fig. 3: Roentgenogram of the left femur (February 7, 1956) shows a solid union with adequate callus formation after eight weeks in a balanced suspension traction.

Associated hyperthyroidism may be overlooked in a patient with widespread polyostotic fibrous dysplasia unless it is borne in mind. It is the purpose of this paper to report one more case of polyostotic fibrous dysplasia associated with hyperthyroidism.

## CASE REPORT

D.H., a ten-year-old Caucasian boy, entered the hospital in January 1960 with a greenstick fracture of left tibia that occurred after minor trauma. His first admission to this hospital was in June 1955, when he sustained a pathological fracture of the upper end of the left femur. Previously, he had been treated for fractures of the lower extremities three times in a country hospital. The first fracture occurred when he was four years old and stumbled over a small suitcase lying on the

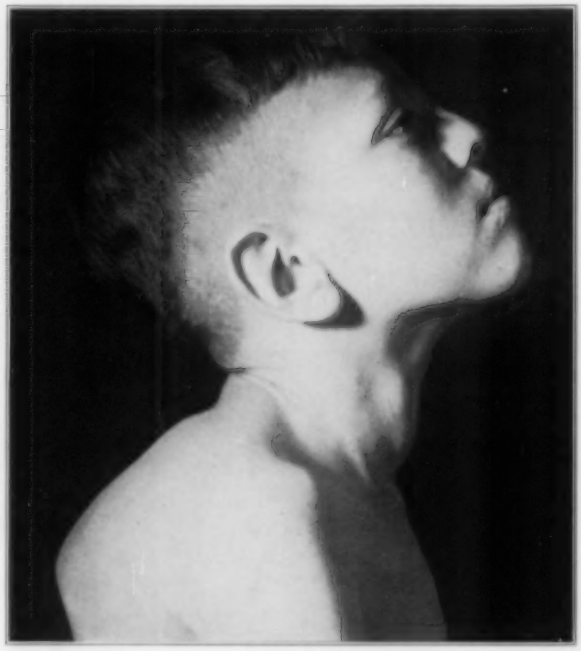


FIG. 4

Photograph of the patient shows the right thyroid mass and winging of the scapulae. The moderate exophthalmos is not well demonstrated.

floor. On his first admission to this hospital, a roentgenogram of left femur showed that a transverse fracture had occurred through a lytic lesion that was suggestive of fibrous dysplasia. Similar lesions were observed in the base of the skull, pelvis, right femur, and both tibiae; but the spine, ribs, arms, hands, and feet were normal. The femoral lesion at the fracture site was curetted completely, and the cavity was filled with chips of homogenous bone. The fracture was treated with suspension and traction. The bone biopsy taken at operation revealed the typical appearance of fibrous dysplasia (Fig. 1).

About one and a half months later, the fracture showed solid union clinically and roentgenographically; the bone chips appeared to be well incorporated in the callus of the healing fracture. The patient had no further difficulty until December 13, 1955, when a transverse fracture occurred at the distal margin of the grafted area. The roentgenogram made on this occasion revealed reabsorption of the bone chips, indicating either recurrence of the disease or reaction to the homogenous bone graft (Fig. 2). This fracture was treated with balanced suspension traction and united solidly in eight weeks (Fig. 3). During the next year the patient was admitted six times to the hospital with twelve fractures involving both femora and tibiae. On each occasion, trivial trauma was the cause of fracture, and at no time were bones in the upper extremities or elsewhere fractured.

After the healing of the last fracture of right femur in 1957, the patient was given physical therapy in an attempt to enable him to walk with crutches. A few months later the crutch-walking was discontinued because of patient's generalized weakness and his mother's fear of his sustaining another fracture. From then on he was confined to a wheelchair. At the last admission in January 1960, a fracture of left tibia had occurred when his foot was gently hit by another boy passing by his wheelchair.

The patient was born normally at full term with a birth weight of seven and a half pounds. No fracture, deformity, jaundice, or respiratory distress was noted at birth or in neonatal life. He was in good health until he sustained his first fracture in 1954.

Neither the parents nor the seven other siblings had any history of fracture or bone deformity. The patient's mother had two patches of brownish pigmentation about two centimeters in diameter on her thigh. The patient gave no history of weight loss, palpitation, shortness of breath, or intolerance to heat during the period prior to admission. The mother stated that the patient had been nervous during the past two years; she had not observed any mass in the region of the thyroid.

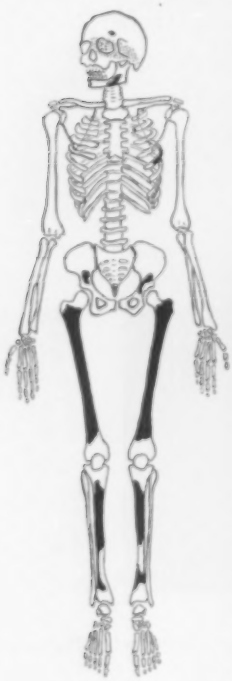


FIG. 5

FIG. 6

Fig. 5: Diagrammatic representation of the distribution of the patient's lesions at the age of eleven years.

Fig. 6: The base of skull (sphenoid and ethmoid) is sclerotic and thickened.

Physical examination in January 1960 revealed a well developed but thin, fragile, pale-looking, and intelligent boy with an asymmetrical face. All his muscles were poorly developed, and there was obvious bilateral bowing deformity of the legs. There was a round bone prominence on left forehead. The thoracic cage was asymmetrical. The spine showed no kyphoscoliosis, but the pelvis was deformed. There was winging of the scapulae caused by weakness of the serratus anterior muscles of undetermined origin (Fig. 4), otherwise the upper extremities were normal. Two butterfly-shaped patches of non-elevated, dark brown pigmentation measuring approximately three by three centimeters with irregular margins were seen over the coccyx. The left testicle was small, hypoplastic, and incompletely descended. His voice was husky; moderate exophthalmos with bluish sclerae was seen on both sides, but was more pronounced on the left. There was a right-sided diffusely enlarged thyroid mass measuring about six by four centimeters, with part of the isthmus contributing to its bulk (Fig. 4).

His blood pressure was 140 systolic and 60 diastolic. His pulse was bounding and 125 per minute. The sleeping pulse varied from 100 to 120 per minute. Pulsations of the carotid arteries

were visible in his neck, and capillary pulsations were present in the fingernails. There were no tremors of the hands. The heart and lungs were normal except for tachycardia. Palpable lymph nodes were found in the neck and axillae. The abdomen was normal. There were no other abnormal physical findings.

The laboratory findings were as follows: the hemogram showed a moderate hypochromic anemia with a hemoglobin of 10.0 grams; the urinalysis was within normal limits; the serum calcium varied from 9.5 to 10.2 milligrams per 100 milliliters; the serum phosphorus was 3.2 to 4.7 milligrams per 100 milliliters; the alkaline phosphatase was 23 to 15 Bodansky units; in twenty-four hours the urinary calcium excretion was 0.027 gram, and the urinary phosphorus excretion was 0.6 gram; the basal metabolic rate varied from + 35 to + 52; the $I^{131}$ uptake was 60 per cent; the protein-bound iodine was 12.5 micrograms per 100 milliliters; the tri-iodothyronine test was 24 per cent. A scintigram showed the whole of the right lobe of the thyroid to be enlarged and func-

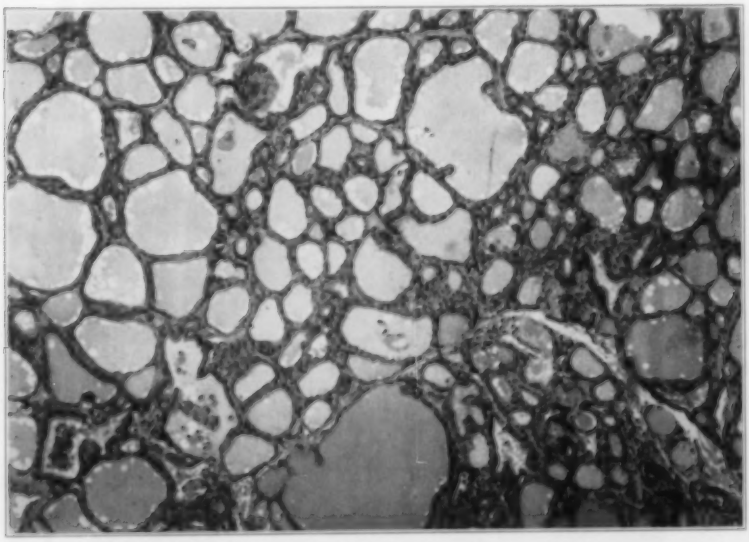


FIG. 7

Thyroid tissue was obtained after four weeks of antithyroid medication. The majority of the component acini are somewhat larger than normal but well formed, lined by cuboidal cells and filled with well stained colloid. In a few areas, hyperplastic changes are seen with small acini which contain little or no colloid.

tioning, but the left lobe was not functioning. In twenty-four hours, the urinary excretion of 17-ketosteroids ranged between 6.1 and 6.8 milligrams; the excretion of 17-ketogenic steroids was 5.3 milligrams, and the excretion of follicle-stimulating hormone was less than 13.2 mouse units. The fasting blood sugar was 80 milligrams per 100 milliliters, and the glucose-tolerance test was within normal limits. The serum proteins and electrolytes, the blood urea nitrogen, and the urinary creatinine were within normal limits. The Kahn test was negative on a previous admission. An anteroposterior roentgenogram of the abdomen was normal.

Roentgenograms of the skeletal system showed that the sphenoid, ethmoid, left frontal bone, left fifth rib, left mandible, pelvis, and the femora and tibiae of both sides were involved (Fig. 5). The spine, clavicles, upper extremities, fibulae, and feet were spared. The base of the skull (sphenoid and ethmoid) was sclerotic and thickened (Fig. 6). The left mandible showed widening and irregular trabeculation; the latter change was also evident in the pelvis. Both femora showed extensive lytic lesions with distortion of the normal bone contour, patches of calcification within the cortex, and a few transverse lines across the shaft. There were typical shepherd's-crook deformities of the femora. A cloud-of-smoke appearance with loss of trabeculation was noted in both tibiae. The bone age and the development of all the bones were within normal limits, being compatible with the patient's chronological age. Because of hoarseness, laryngoscopy was carried out and revealed paralysis of the right vocal cord.

The patient was given Lugol's solution and tapazole for four weeks, and then a complete right hemithyroidectomy was performed on March 7, 1960. The pathological examination of the thyroid tissue showed nodular colloid goiter with hyperplasia (Fig. 7).

After the operation, the patient's course was uneventful, and his protein-bound iodine fell to a normal level. Laryngoscopy, repeated one month after the operation, showed complete recovery of the paralysis of the right vocal cord. Lugol's solution was continued until the eleventh postoperative day. At the beginning of the fifth week, the patient was given thyroid, three-quarter grain, twice a day, for a mild degree of hypothyroidism had developed. He was transferred to a physical restoration center where he regularly received physiotherapy.

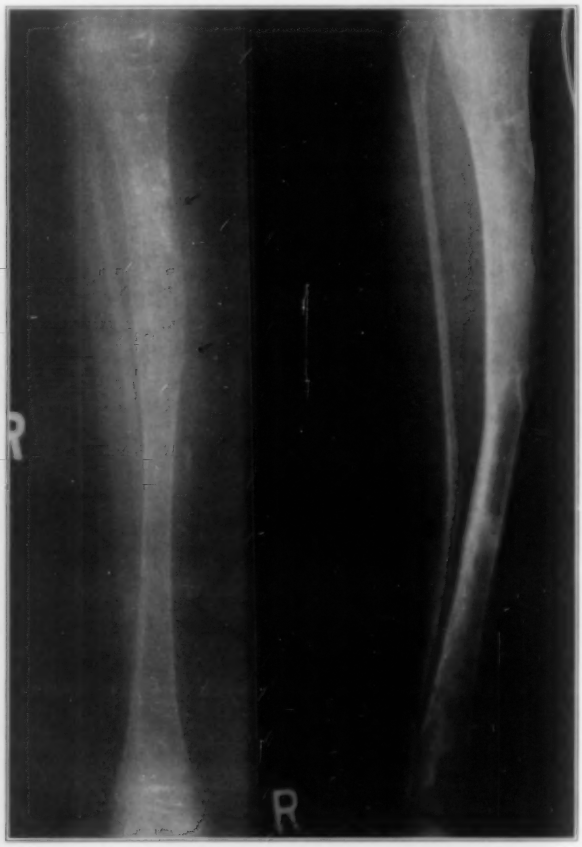



FIG. 8-A FIG. 8-B

Fig. 8-A: Roentgenogram of the right tibia made before thyroidectomy. Note a "cloud-of-smoke" appearance, thinned out cortex, two fracture lines, and marked osteoporosis.

Fig. 8-B: The same tibia approximately fifteen months after the right hemithyroidectomy showing thickening of the cortex.

When he was last examined on June 5, 1961, he walked with the aid of crutches and wore long braces. He had been told to use the crutches, but he was able to walk without them. He had a feeling of well-being; and his weight gain was satisfactory. The thyroid-function studies and physical findings indicated an euthyroid range: The patient requires thyroid, three-quarter grain, twice a day at the present time. Remarkable changes were noted in the roentgenograms made at the last visit; these showed a generalized thickening of the cortex of the bones and some improvement of osteoporosis (Figs. 8-A and 8-B). Since the operation he has sustained one more fracture of the right tibia in August 1960 when he fell; this was treated with a toe-to-groin cast and healed in six weeks.

## DISCUSSION

The coexistence of endocrinal dysfunction with polyostotic fibrous dysplasia is well known. Next to precocious puberty and accelerated skeletal growth and

maturation, thyroid dysfunction is the most common endocrinal disturbance. The relatively frequent occurrence of deranged thyroid function in a rare disease such as polyostotic fibrous dysplasia appears to be more than mere coincidence. Of the patients with definite hyperthyroidism reported by Yettra and Starr (six), Lagèze and associates (one), and ourselves (one), three were male and five were female; two of the girls had precocious puberty as well. In all these patients, hyperthyroidism supervened some years after the initial recognition of polyostotic fibrous dysplasia. Pathological examination of thyroid gland has always revealed either adenomatous hyperplasia or colloid goiter.

The etiology and pathogenesis of polyostotic fibrous dysplasia are unknown. The syndrome is not considered to be hereditary or familial. Hirsch reported on three siblings with generalized osteitis fibrosa who at one time were considered to have polyostotic fibrous dysplasia, but this diagnosis was questioned by subsequent authors [10,21,22]. Coarctation of the aorta, congenital acyanotic heart disease, arteriovenous fistula of the left leg and arm, patent foramen ovale, a rudimentary left kidney, vascular and pigmented nevi, pseudo-xanthoma elasticum, and Meckel's diverticulum have all been found in association with polyostotic fibrous dysplasia. However, the incidence of congenital anomalies in patients with this disease is not greater than in the general population. Most of the authors agree with the view held by Jaffe and Lichtenstein that this disease is the result of a developmental defect that manifests itself predominantly by the skeletal lesions, which are amplified by the various extraskeletal abnormalities.

The clinical recognition of hyperthyroidism may be difficult in cases other than those associated with sexual precocity unless the clinician is constantly aware that hyperthyroidism may be a rare associated endocrinal disturbance. It appears that in our patient, thyrotoxicosis, which was a contributing factor in the patient's inability to walk, was overlooked initially because of the extensive bone lesions, although the exact time of the onset of hyperthyroidism is difficult to determine. The multiple recurrent fractures in our patient all united within a reasonable time (Figs. 2 and 3). A normal amount of callus formed at each fracture site, but it thinned out rapidly, suggesting either replacement by dysplastic fibrous tissue or rapid remodelling. Progressive bone deformity of the femora was evident roentgenographically even after the fractures had healed, and the bone lesions progressed rapidly during the period of observation. The bone lesions in this disease are known to progress until puberty is reached.

In contrast to reports of other authors, we found increased excretion of 17-ketosteroids in the urine of our patient. This was probably due to the metabolic changes caused by the thyrotoxicosis, as was suggested by Levin and Daughaday and by Peterson. The osteoporosis seen in our patient was more marked than is ordinarily observed in fibrous dysplasia. This was undoubtedly the result of the primary bone disease and disuse atrophy, but it may have been accentuated by thyrotoxicosis. The skin pigmentation was present but there was no sexual precocity. The initially elevated alkaline phosphatase dropped to normal when the fractures healed. As in the reports on other patients, normal values of calcium and phosphorus were found in the serum and urine of our patient. The hypoplastic left testicle was noted as an associated anomaly, and the paralysis of the right vocal cord was most likely the result of pressure caused by the enlarged thyroid.

## SUMMARY

The case of a ten-year-old boy with extensive segmental involvement of the skeleton with polyostotic fibrous dysplasia, multiple fractures, thyrotoxicosis, and a hypoplastic left testicle, an associated anomaly, is reported. This brings the number of such cases reported in the literature to eight.

REFERENCES


1. Albright, Fuller; Butler, A. M.; Hampton, A. O.; and Smith, Patricia: Syndrome Characterized by Osteitis Fibrosa Disseminata, Areas of Pigmentation and Endocrine Dysfunction, with Precocious Puberty in Females. Report of Five Cases. New England J. Med., **216**: 727–746, 1937.
2. Albright, Fuller: Polyostotic Fibrous Dysplasia: A Defense of the Entity. J. Clin. Endocrinol., **7**: 307–324, 1947.
3. Albright, Fuller, and Reifenstein, E. C., Jr.: The Parathyroid Glands and Metabolic Bone Disease. Selected Studies. Baltimore, The Williams and Wilkins Co., 1948.
4. Caldwell, G. A., and Broderick, T. F., Jr.: Polyostotic Fibrous Dysplasia in One of Negro Twin Girls. Ann. Int. Med., **27**: 114–126, 1947.
5. Dawes, M. L., and Yardley, J. H.: Fibrous Dysplasia of Bone. Am. J. Med. Sciences, **234**: 590–606, 1957.
6. Dockerty, M. B.; Ghormley, R. K.; Kennedy, R. L. J.; and Pugh, D. G.: Albright's Syndrome. (Polyostotic Fibrous Dysplasia with Cutaneous Pigmentation in Both Sexes and Gonadal Dysfunction in Females). Arch. Int. Med., **75**: 357–375, 1945.
7. Falconer, M. A., and Cope, C. L.: Fibrous Dysplasia of Bone with Endocrine Disorders and Cutaneous Pigmentation (Albright's Disease). Quart. J. Med., **11**: 121–154, 1942.
8. Furst, N. J., and Shapiro, Robert: Polyostotic Fibrous Dysplasia: Review of the Literature with Two Additional Cases. Radiology, **40**: 501–515, 1943.
9. Gaupp, Vera: Pubertas praecox bei Osteodystrophia fibrosa. Monatsschr. f. Kinderh., **53**: 312–322, 1932.
10. Hirsch, J. S.: Generalized Osteitis Fibrosa. Radiology, **13**: 44–84, 1929.
11. Horwitz, Thomas, and Cantarow, Abraham: Polyostotic Fibrous Dysplasia. Report of a Case. Arch. Int. Med., **64**: 280–285, 1939.
12. Lagèze, P.; Chassagnon, C.; and Maitrepierre, J.: Syndrome d'Albright et hyperthroidie. (A propos d'une observation). Lyon Med., **194**: 201–207, 1955.
13. Lange, Kurt: Zur Ostitis fibrosa generalisata (Recklinghausen). Zentralbl. f. Chir., **65**: 2368–2373, 1938.
14. Levin, M. E., and Daughaday, W. H.: Influence of Thyroid on Adrenocortical Function. J. Clin. Endocrinol., **15**: 1499–1511, 1955.
15. Lichtenstein, Louis: Polyostotic Fibrous Dysplasia. Arch. Surg., **36**: 874–898, 1938.
16. Lichtenstein, Louis, and Jaffe, H. L.: Fibrous Dysplasia of Bone. A Condition Affecting One, Several or Many Bones, the Graver Cases of Which May Present Abnormal Pigmentation of Skin, Premature Sexual Development, Hyperthyroidism or Still Other Extraskeletal Abnormalities. Arch. Pathol., **33**: 777–816, 1942.
17. Peterson, R. E.: The Influence of the Thyroid on Adrenal Cortical Function. J. Clin. Invest., **37**: 736–743, 1958.
18. Sternberg, W. H., and Joseph, Vera: Osteodystrophia Fibrosa Combined with Precocious Puberty and Exophthalmic Goiter. Am. J. Dis. Child., **63**: 748–783, 1942.
19. Summerfeldt, Pearl, and Brown, Alan: Osteodystrophia Fibrosa. Am. J. Dis. Child., **57**: 90–101, 1939.
20. Thannhauser, S. J.: Neurofibromatosis (von Recklinghausen) and Osteitis Cystica Localisata et Disseminata (von Recklinghausen). Medicine, **23**: 105–148, 1944.
21. Vines, R. H.: Polyostotic Fibrous Dysplasia. Arch. Dis. Child., **27**: 351–355, 1952.
22. Warrick, C. K.: Polyostotic Fibrous Dysplasia—Albright's Syndrome. A Review of the Literature and Report of Four Male Cases, Two of which were associated with Precocious Puberty. J. Bone and Joint Surg., **31-B**: 175–183, May 1949.
23. Yettra, Maurice, and Starr, Paul: Polyostotic Fibrous Dysplasia Associated with Hyperthyroidism. J. Clin. Endocrinol., **11**: 312–321, 1951.

# Replacement of the Shaft of the Phalanx with Iliac Bone

BY GEORGE MIYAKAWA, M.D., CHARLESTON, WEST VIRGINIA

On January 31, 1955, a twelve-year-old white boy was seen for the complaints of severe pain and swelling of the right index finger. The swelling had occurred during the previous six to eight

FIG. 1

Original roentgenogram, made in January 1955, shows the large cyst of the proximal phalanx.

FIG. 2

Iliac graft in place, March 1955.

FIG. 3

By June 1955, there had been gradual reshaping of the graft and continued growth of phalanx.

FIG. 4

By June 1958, the intramedullary canal had begun to appear.

months; severe pain began two weeks before he was seen, after minor trauma.

Examination showed marked swelling of the right index finger, with local heat, suggestive of spina ventosa. The finger was held rigidly, and any attempt to flex the interphalangeal joints aggravated the pain.

The patient was admitted to the Charleston General Hospital, where the routine laboratory examinations, including a tuberculin test with precipitated protein derivative, were negative. Roentgenograms showed what appeared to be a large cystic lesion of the proximal phalanx (Fig. 1).

At operation, February 17, 1955, an incision was made along the radial aspect of the proximal phalanx of the right index finger. The lumbrical and extensor tendons were retracted dorsally. The cortical bone of the phalanx was found to be thin and parchment-like. Due to the markedly deformed enlargement of the phalanx, it did not appear feasible to fill this area completely with bone

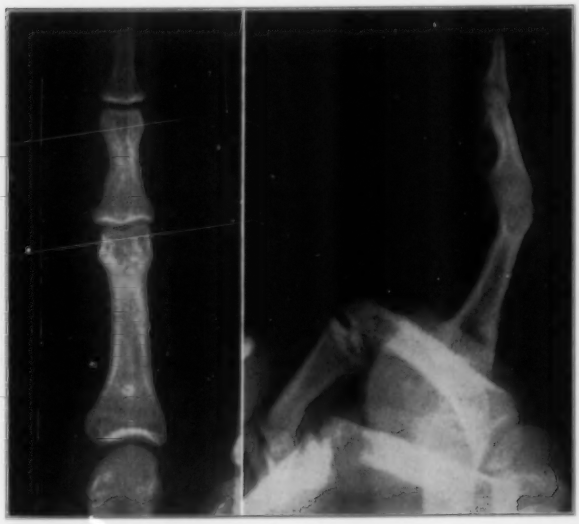


FIG. 5

By July 1960, normal maximum growth had been attained, and the intramedullary canal was now visible.

chips. Therefore, the parchment-like bone was resected with a knife, leaving the proximal epiphysis and the distal osteocartilaginous surface. An iliac graft was removed and roughly shaped to resemble a phalanx. This was inserted between the two remaining osteocartilaginous ends (Fig. 2). The fingers were immobilized over a roller bandage. Microscopic examination, as reported by the pathologist, showed the removed thin wall to be a typical cyst of bone. The patient's condition was satisfactory after operation, and he was discharged on the eighth day. The incision healed *per primam*, and motion was begun after six weeks.

This patient has been followed closely with annual roentgenograms. By April 1956, there was a full range of painless motion.

The beginning development of the intramedullary canal is seen in Figs. 4 and 5. Continued growth at the proximal epiphysis and progressive remodeling of the graft to simulate a normal phalanx are shown in Figs. 4 and 5. The clinical appearance of both index fingers is identical.

## COMMENT

1. A case of nearly complete replacement of a shaft of a phalanx is presented.
2. There is gradual, spontaneous remodeling of the large bone graft to simulate a normal phalanx.
3. The gradual development of intramedullary canal is noted.
4. Epiphyseal growth, as well as a full range of motion, has been maintained.

# Proceedings

## THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Twenty-eighth Annual Meeting of The American Academy of Orthopaedic Surgeons was held at the Americana, Miami Beach, Florida, January 9 through 13, 1961, under the Presidency of Dr. Hugh Smith.

At the Second Executive Session, the new President, Dr. J. Vernon Luck, Los Angeles, California, was inducted into office. The following officers were elected:

*President-Elect:* Frank E. Stinchfield, M.D., New York, N.Y.;

*Vice-President:* R. Beverly Raney, M.D., Chapel Hill, North Carolina;

*Treasurer:* Carroll B. Larson, M.D., Iowa City, Iowa;

*Secretary:* Clinton L. Compere, M.D., Chicago, Illinois;

*Librarian-Historian:* Edward T. Smith, M.D., Houston, Texas.

*Executive Committee:*

H. Relton McCarroll, M.D., St. Louis, Missouri;
Hugh Smith, M.D., Memphis, Tennessee;
Harold A. Sofield, M.D., Oak Park, Illinois;
George J. Garceau, M.D., Indianapolis, Indiana.

*Junior Members of the Executive Committee:*

Paul H. Curtiss, Jr., M.D., Cleveland, Ohio;
Daniel C. Riordan, M.D., New Orleans, Louisiana.

*Chairman of the Program Committee:* Marcus J. Stewart, M.D., Memphis, Tennessee;

*Chairman of the Committee on Scientific Investigation:* Charles H. Herndon, M.D., Cleveland, Ohio;

*Chairman of the Committee on Scientific Exhibits:* Earl S. Leimbacher, M.D., Joliet, Illinois;

*Chairman of the Committee on Instructional Courses:* Paul R. Lipscomb, M.D., Rochester, Minnesota;

*Chairman of the Committee on Audio-Visual Education:* Robert J. Joplin, M.D., Brookline, Massachusetts.

Dr. Charles V. Heck, Chicago, Illinois, was appointed *General Chairman* for the next Annual Meeting, which will be held in Chicago, Illinois, January 27 through February 1, 1962.

Summaries of the papers presented at the Scientific Sessions follow:

### Combined Program of the Orthopaedic Research Society and The American Academy of Orthopaedic Surgeons

**Repair of Knee Ligaments in Dogs. I. The Lateral Collateral Ligament.** Dr. Don H. O'Donoghue [1], Capt. Charles A. Rockwood, Jr., Dr. Basilius Zaricznyj, and Dr. Rex Kenyon. (To be published in a subsequent issue of *The Journal of Bone and Joint Surgery.*)

**Some Bioelectric Aspects of Regeneration.** Dr. Robert O. Becker [2]. (J. Bone and Joint Surg., **43-A**: 643–656, July 1961.)

**Evaluation of Hellstadius' Experiment.** Dr. Bertram M. Kummel [3] presented his findings after repeating and refining Hellstadius' experiment on longitudinal bone growth. After extraperiosteal excision of the distal ulnar epiphysis, Hellstadius observed longitudinal growth of the ulna and concluded that growth of the diaphysis can occur in the absence of epiphyseal cartilage. Dr. Kummel repeated these experiments as controls and, in addition, did similar experiments in which the distal end of the ulna was covered with a flap of skin as a barrier to the formation of a fibrous-tissue membrane between the distal end of the ulna and the radial epiphysis. In the animals without a skin flap, a fibrous membrane formed between the distal end of the ulna and radial epiphysis, and lengthening of the ulna occurred in association with ulnar deviation of the radius. In the animals with a skin flap, in which a fibrous membrane did not form, lengthening of the ulna and deformation of the radius did not occur. Despite the small number of animals used and some inconsistent results, Dr. Kummel concluded that the growth of the ulna in the Hellstadius experi-

1. Lee at 10th Street, Oklahoma City 3, Oklahoma.
2. Veterans Administration Hospital, Syracuse 10, New York.
3. 34 Elm Street, Morristown, New Jersey.

ment is a function of the growth of the radial epiphysis, and that failure to appreciate the importance of the fibrous-tissue membrane had led to an erroneous interpretation of the findings in the original experiment.

**Post-Fracture Vascular Phenomena and Long Bone Overgrowth in the Immature Skeleton.** Dr. James B. Wray [4] and Harold O. Goodman, Ph.D. (To be published in a subsequent issue of *The Journal of Bone and Joint Surgery*.)

**Morquio's Disease and Dysplasia Epiphysalis Multiplex—A Study of the Epiphyseal Cartilage in Seven Cases.** Dr. Carl E. Anderson [5], Dr. Harold A. Harper, Dr. Jackson T. Crane, and Dr. T. Wesley Hunter described the pathological findings after biopsy of the epiphyseal plate in patients who had either Morquio's disease or dysplasia epiphysalis multiplex. The similarity in the microscopic and pathological findings led the authors to conclude that Morquio's disease, dysplasia epiphysalis multiplex, and achondroplasia have a common pathological basis in disordered epiphyseal-chondrocyte maturation and function. They therefore suggested the term *chondrogenic dwarfism* as a suitable generic designation. On the basis of microscopic findings, they feel that this group of cases can be readily differentiated from Hurler's syndrome because of the absence of the storage phenomenon. The essential pathological finding in both Morquio's disease and dysplasia epiphysalis multiplex is the failure of the epiphyseal chondrocytes to reach the zone of ossification in adequate numbers or in a fully developed hypertrophic state.

**Biochemical Studies on the Pathogenesis of Collagen-Tissue Changes in Alkaptonuria.** Dr. Robert A. Milch [6] reported his observations of the interactions of homogentisic-acid solutions and bovine-hide-powder collagen. This is a portion of a research study of the biochemical mechanisms in the production of alkaptonuric arthritis. The author pointed out that alkaptonuria is an inborn error of metabolism characterized by an inherited absence of the enzyme homogentisic-acid oxidase. The earliest manifestation of this disease is an abnormal renal excretion of homogentisic acid, an otherwise normal intermediary product of phenylalanine and tyrosine metabolism. The kidney appears to be otherwise structurally and functionally normal but excretes this abnormal product, which turns the urine blue-black on standing (autoxidation). Many non-mineralized connective tissues of affected persons become pigmented, firm, and inelastic; soon thereafter, degenerative arthritis supervenes, first in the axial skeleton and later in all the joints.

By mixing various solutions of homogentisic acid and homogentisic acid autoxidation polymers with isoelectric and n-acetylated bovine-hide-powder collagen preparations, Dr. Milch studied swelling and absorption by various means, including ultra-centrifugation, column chromatography, electron microscopy, and enzyme-degradation studies. These showed that monomeric, unoxidized homogentisic acid does not bind appreciably to hide-powder collagen preparations, but that extensive binding occurs with the autoxidized, polymerized homogentisic-acid solutions. The author suggested that this *in vitro* system, which is similar to tanning of hides by quinones and hardening of insect exoskeletons, probably accounts for the development of degenerative-joint disease in persons with alkaptonuria, since there was no evidence of interaction of any homogentisic-acid solutions with various mucopolysaccharides.

### The American Academy of Orthopaedic Surgeons

**Metallic Hip Arthroplasty. A Follow-up Study.** Dr. Arthur H. Stein, Jr.[7], and Dr. William S. Costen reported that of 251 operations done for insertion of an internal hip prosthesis at the Barnes Hospital in St. Louis, ninety-one patients returned for examination and forty-eight were evaluated by questionnaire. In the 139 operations evaluated, 112 were considered to have a successful result. In twenty-two procedures the outcome was unsuccessful, and in five instances the patient was considered to be too senile to make the evaluation of the operation valid.

A comparison of the final result of the operations indicated that the patients operated on for fresh fracture showed the best end results; they were significantly better than when the operation had been done as a salvage procedure for a hip fracture that had failed to heal successfully after initial treatment. Although the over-all complication rate between the fresh-fracture group and the salvage group was not significantly different, a high incidence of fracture of the femur at the time of operation for salvage of an old fracture was found to be a significant hazard. A postoperative mortality rate of 11.8 per cent in the group of patients with fresh fracture appeared to be high. It must be

4. Upstate Medical Center, State University of New York, Syracuse 10, New York.
5. 1150 Montgomery Drive, Santa Rosa, California.
6. The Johns Hopkins Hospital, Baltimore 5, Maryland.
7. 600 South Kingshighway, St. Louis 10, Missouri.

remembered, however, that in this particular group of patients, the cases selected for replacement prosthesis is a biased group. The surgeons elected to do the procedure in the patient who was considered to be a poor risk and thus the mortality rate may be somewhat distorted.

In the group of patients with fresh fracture, the Hueter approach gave significantly less pain than did the Smith-Petersen approach, which suggests that this limited approach should be used whenever it is possible to do the operation through this exposure. It appears that the use of the stem prosthesis for femoral-head replacement in fresh femoral-neck fractures is a justifiable and valuable procedure.

In the group of patients operated on for malum coxae senilis, the end result was not as good as when the operation was done either for a fresh fracture or as a salvage procedure in an old fracture of the femoral neck. The Judet prosthesis inserted through the Gibson approach resulted in more hip pain than did a Frederick R. Thompson prosthesis done through a Smith-Petersen approach. The degree of hip pain was found to be significantly less and the end results significantly better in the group of patients with malum coxae senilis when the patient was slender.

Although the complication rate in the entire group of 251 patients was 25.5 per cent, it must be remembered that this embodies the surgeons' earliest experiences with hip prosthesis; they hope with time, that the incidence of complications will decrease. They found it quite significant that, when a major complication occurs, the chances of a successful outcome are significantly reduced.

**Crawford Adams Cup Arthroplasty. A Review of Fifty Cases.** Dr. T.L. Waring [8] and Dr. L.D. Anderson. (J.Bone and Joint Surg., **43-A:** 431–442, Apr. 1961.)

**Arthroplasty of the Hip. A Follow-up Study of Prosthetic Replacement of the Femoral Head.** Dr. Joseph S. Barr [9], Dr. James F. Donovan, and Dr. David W. Florence presented a follow-up study of 164 patients from the Massachusetts General Hospital treated with Austin Moore prostheses for various hip conditions—fresh and ununited intracapsular hip fractures, avascular necrosis of the femoral head, and degenerative and rheumatoid arthritis. Of the 164 patients, forty-five were considered for final evaluation, the average follow-up being 5.8 years.

Results were satisfactory in 77 per cent of the patients, as measured by rather rigid criteria, and about 13 per cent approached normal hip function. None of these had acetabuloplasty. Fifty per cent of the unsatisfactory results were in patients treated for congenital dislocation of the hip. Only 13 per cent of the patients had sufficient pain to be considered unsatisfactory and 69 per cent had little or no pain. Thirty-three per cent walked without a cane or crutch, and 22 per cent could walk a mile without interruption. One-third of the patients had no deformity. The excellent results were seen only in patients with fractures. None of the patients with degenerative arthritis had better than a satisfactory result.

In degenerative arthritis, the Austin Moore prosthesis was considered as satisfactory as the mold arthroplasty. It was not thought to be as good as mold arthroplasty in rheumatoid or old septic arthritis. The authors feel that the stem-prosthesis operation is the best treatment for certain intercapsular fractures of the neck of the femur, particularly those in which fixation is unstable or those with comminution or aseptic necrosis. Acetabular reconstruction did not yield excellent results. Reconstruction of neuropathic joints was unsuccessful.

The authors gave details of the operative procedure and stressed the need for postoperative physical therapy and cooperation of the patient. There were a few complications, such as ectopic-bone formation, interpelvic protrusion, anteversion, settling of the prosthesis, and dislocation.

They feel that although mold arthroplasty and prosthetic arthroplasty of the hip have their limitations, either procedure yields an acceptable number of satisfactory results or better in properly selected and properly treated cases.

**Arthrodesis of the Hip. An Analysis of 371 Cases.** Dr. Paul R. Lipscomb [10] and Dr. Frank E. McCaslin, Jr., analyzed 371 procedures of arthrodesis of the hip performed at the Mayo Clinic from 1914 through 1959. One hundred and sixteen patients had tuberculosis of the hip, ninety had destructive arthritis other than tuberculosis, twenty-nine had congenital dislocation, and 136 had post-traumatic or degenerative lesions. Whereas, in the decade from 1920 to 1929, 57 per cent of hip arthrodeses were performed for tuberculosis and 14 per cent for post-traumatic or degenerative lesions, in the last decade only 13 per cent were performed for tuberculosis and 53 per cent for post-traumatic or degenerative lesions.

Many types and combinations of surgical procedures were used in the series. Union was satis-

8. 869 Madison Avenue, Memphis 3, Tennessee.
9. 275 Charles Street, Boston 14, Massachusetts.
10. 200 First Street, S.W., Rochester, Minnesota.

factory in 78 per cent of the hips after the first operation. The poorest rate of union (68 per cent) was in patients who underwent the Brittain operation; these patients often presented very difficult problems. (In selected instances, the Brittain procedure still has a very definite place.) The first intertrochanteric osteotomy to be done at the Mayo Clinic in combination with arthrodesis of the hip was performed in 1926. This was done on eighty patients whose condition was followed adequately; sixty-nine (86 per cent) obtained union after the first surgical procedure. This percentage has been increased to 88 in the past few years by adherence to principles involving the use of: (1) an intra-articular and extra-articular procedure with stimulation of osteogenesis by massive autogenous-bone grafts; (2) osteotomy of the femur just below the site of fusion, thereby eliminating the strain of the long lever arm of the lower extremity; and (3) adequate internal as well as external fixation.

For external fixation the authors now use a carefully molded plaster-of-Paris cast which extends from the mid-thoracic cage to the ankle. This allows the patient limited walking with crutches; usually, he is able to leave the hospital after two to three weeks.

Dr. Lipscomb and Dr. McCaslin believe that arthrodesis is the procedure of choice for most active young or middle-aged persons who require extensive surgical reconstruction of the hip, provided that the opposite hip, the lumbar spine, and both knees are normal.

**Surgery of the Forefoot in Rheumatoid Arthritis.** Dr. Mack L. Clayton [11] and Dr. John D. Leidholt noted that deformities of the feet in chronic rheumatoid arthritis are often the most disabling features of the disease. The deformities consist of varying degrees of hallux valgus and bunion formation, cock-up toes, and depressed metatarsal heads. Even proper shoe-fitting and supports may fail to control symptoms. Painful weight-bearing after failure of conservative measures was considered the indication for surgical treatment. The surgical technique consisted in adequate excision of bone, including metatarsal heads and bases of the proximal phalanges. Surgery was performed as one procedure through a transverse incision. The authors said that the functional and cosmetic results were satisfactory in thirty-five feet operated on. Twenty-five patients were followed for more than a year, the longest follow-up was seven years.

**Eosinophilic Granuloma of Bone.** Dr. John L. Sbarbaro, Jr.[12], and Dr. Kenneth C. Francis.

**Presidential Address. Orthopaedic Payola.** Dr. Hugh Smith [13]. (J. Bone and Joint Surg., **43-A**: 141–146, Jan. 1961.

**Late Functional Results Following Fracture of the Calcaneus.** Dr. Louis J. Levy [14], Dr. Cuvier P. Lipscomb, Dr. Henry C. McDonald, and Dr. Charles P. Davis presented an analysis of their experience with fractures of the calcaneus in forty patients, who were followed chiefly by questionnaire for an average of five years after injury. The patients tended to improve for two or three years, and 75 per cent had satisfactory results at five years after injury. On the basis of the authors' survey, they concluded that the more accurately the structures were restored to normal, the better the end result. They felt that it is necessary to restore the length of the calcaneus and to obtain a smooth subtalar joint surface. Fractures involving the posterior facet can be treated satisfactorily by the Palmer technique of open reduction if the fractures are not extensively comminuted. Extensively comminuted fractures are probably better treated by triple arthrodesis. Simple removal of spurs projecting into the soft tissues of the heel may bring marked relief to most patients with this complication.

**Diamond Split Nail for Fractures in the Lower Third of the Femur, Tibia, and Humerus.** Dr. Dana M. Street [15] and Dr. David G. Vesely.

**Posterior Traumatic Dislocation of the Shoulder.** Dr. Werner N. Nobel [16] said that compared with anterior dislocation of the shoulder, posterior dislocation is a rare condition that is often missed on the first examination. Diagnosis is made difficult by the fact that clinical signs are sometimes minimum or absent. The diagnosis is suggested by locking in adduction and internal rotation and is established by palpation of the head posteriorly. This is often easier with the arm

11. 1855 Gaylord Street, Denver 6, Colorado.
12. Hahnemann Hospital, Philadelphia, Pennsylvania.
13. 869 Madison Avenue, Memphis 3, Tennessee.
14. 918 Eighth Avenue, Ft. Worth 4, Texas.
15. University of Arkansas Medical Center, Little Rock, Arkansas.
16. 474 Main Street, Greenfield, Massachusetts.

in forward flexion. Many of the clinical signs suggested in the literature, such as flattening of the anterior shoulder contour, prominence of the coracoid or acromial process, and inability to rotate the humerus externally, do not differentiate posterior dislocation, as they may be found in anterior dislocation as well.

One of the chief reasons for missing the diagnosis is that the routine anteroposterior roentgenograms often look normal. An axillary view, or an oblique view if the arm cannot be abducted, is of prime diagnostic importance.

Prompt recognition and reduction of acute dislocations are essential, as prognosis for a good result deteriorates rapidly with delay. Closed reduction should be gentle, retracing the path of dislocation. Choice of surgical procedure for repair of recurrent or irreducible posterior dislocations should be determined by the specific condition. The posterior approach of Kocher, with its modifications, affords a good exposure.

Of ten cases of posterior dislocation presented by the author, four were acute, five were recurrent (one bilateral), and one was permanent. One of the acute cases was an unusual posterior subglenoid dislocation. There were three cases of snapping shoulder which proved to be recurrent posterior dislocations, two of them due to congenital joint laxity.

**Axial Fixation of Forearm Fractures.** Dr. Frederick M. Marek [17] presented a technique for fixation of unstable fractures of the forearm in adults. He said the essential feature is a resilient square-shaped nail introduced from the dorsal surface of the distal end of the radius just above Lister's tubercle. Introduction from this site rather than from the radial styloid process allows for the irregular shape of the medullary canal of the radius and overcomes many of the difficulties encountered by previous methods. Fixation of both radius and ulna is particularly firm, as demonstrated by five patients who were originally treated without external immobilization. Meticulous technique with anatomical reduction and minimum stripping at the fracture site was emphasized by the author.

Of thirty-five patients treated, thirty-one (forty-nine fractures) were available for detailed analysis. All fractures resulted in prompt bone union in an average of three and one-half months. There was no mortality and there were no infections.

**Giant-Cell Tumor—Menace or Myth.** Dr. Ernest E. Aegerter [18] emphasized that during the last two decades refinement of the diagnostic criteria for giant-cell tumor of bone has caused this diagnosis to be made with less and less frequency. During these two decades six new diseases of bone have been identified, each frequently characterized by the presence of giant cells; giant-cell forms of fibrosarcoma and osteosarcoma have also been described. The author contended that many of these lesions have been misdiagnosed giant-cell tumor and that the erratic behavior of lesions diagnosed as giant-cell tumor suggests that the term *giant-cell tumor* is not specific, Grade I including a variety of processes characterized by a giant-cell reaction, Grade II being giant-cell fibrosarcoma, and Grade III, giant-cell osteosarcoma. He stressed that at present there is insufficient evidence to prove or disprove whether giant-cell tumor is a menace or a myth. With more critical evaluation of roentgenograms and less eagerness on the part of pathologists to make the easy diagnosis of giant-cell tumor when reviewing microscopic sections containing giant cells, proof or disproof may be forthcoming.

**Factors Influencing the Result in Fractures of the Femoral Neck.** Dr. Henry H. Banks [19] surveyed the treatment of femoral-neck fractures at the Peter Bent Brigham Hospital from 1939 to 1958. Of the 301 fresh intracapsular fractures treated in 296 patients, there were 213 displaced fractures and eighty-eight impacted fractures of the femoral neck. Of the displaced fractures, eighty-nine healed and thirty-four did not. Because the fracture could not be reduced by closed manipulation in aged patients, the femoral head was primarily replaced by an Austin Moore prosthesis in eleven patients. Seventy-three patients, including thirty-nine who died within ten months of surgery, had inadequate follow-up. Six patients died before any surgery could be performed. Of the eighty-eight impacted fractures, fifty-seven healed and two did not. Twenty-nine had inadequate follow-up, including five patients who died early after surgery.

Dr. Banks said that the factors that influence the result of treatment in fractures of the femoral neck include the patient, the fracture itself, the surgeon, the roentgenogram, postoperative care, and aseptic necrosis. Whether the injury is valgus or vertical, comminuted or not, healing will ordinarily result if a displaced fracture can be properly reduced and carefully immobilized with internal

17. 1148 Fifth Avenue, New York 28, N.Y.
18. Temple University School of Medicine, Philadelphia, Pennsylvania.
19. 721 Huntington Avenue, Boston 15, Massachusetts.

fixation. This is particularly true if postoperative care is adequate. Attention to these fine details by an experienced surgeon should decrease the incidence of non-union. In younger persons, fractures which cannot be reduced by closed technique should be treated by open reduction. A similar problem in the aged is well treated by excision of the femoral head and replacement by an Austin Moore prosthesis. Aseptic necrosis is still a serious problem which bears continued study.

**A Continuing End-Result Study of Intracapsular Fractures of the Neck of the Femur.** Dr. J. William Fielding [20], Dr. Hudson J. Wilson, Jr., and Dr. Robert E. Zickel presented a statistical review of 179 intracapsular fractures treated at St. Luke's Hospital from 1952 to 1959. Only 136 of these could be analyzed because twenty-six patients died before the end results were known and seventeen were lost to follow-up. The average follow-up was three and three-quarters years.

Thirty-three fractures were undisplaced; all but one were treated by a Smith-Petersen nail and all united. Avascular necrosis developed in four patients.

One hundred and three fractures were displaced; five were treated by primary prosthesis, two by a Jewett nail, sixty-six by a Smith-Petersen nail, and thirty by a Pugh nail.

Forty-four per cent of the fractures treated by the Smith-Petersen nail failed to unite, and avascular necrosis developed in 24 per cent of the patients with united fractures.

Ten per cent of the fractures treated by the Pugh nail failed to unite, and circulatory changes developed in 22 per cent of the patients with united fractures.

The series of thirty fractures treated with Pugh nails was too small to be statistically significant, but when compared with the known failure rate of the Smith-Petersen nail, the early results were encouraging. The authors felt that the telescoping appliance offers the greatest advance in the fixation of displaced intracapsular fractures since the introduction of the Smith-Petersen nail. It was further indicated that every effort should be made to obtain a united fracture rather than resorting to immediate insertion of a prosthesis.

### Kappa Delta Award Paper

**Experimental Investigations of Large and Small Fragment Bone Implants and Extracts of Heterogenous Bone.** Dr. Kirk J. Anderson [21] first reviewed the background of his studies based on 948 specimens of large and small-fragment autogenous, homogenous, and heterogenous-bone implants in the anterior chamber of the eye of the rat. In particular, the experiments with heterogenous bone were emphasized. Results demonstrated that heterografts of calf bone make no contribution of living new bone. The large-fragment fresh bone heterograft incited a mild inflammatory reaction comparable to the fresh homograft. Storage in saline solution led to a diminished inflammatory reaction, whereas storage of the heterograft in homologous bovine plasma increased the host inflammatory reaction. Dr. Anderson pointed out that modern immunologic techniques indicate that the major antigenicity of bone appears to be related to the serum and marrow cellular elements. Small-fragment heterogenous calf-bone implants manifested a strong inflammatory and foreign-body reaction. The implication of these findings on clinical bone-grafting were that fresh and saline-stored large-fragment calf-bone heterografts compare to fresh and preserved homografts of bone. The small-fragment heterograft, like the autograft and the homograft, is inferior to the large-fragment bone graft since fragmentation destroys osteogenic activity of the bone graft and produces a more severe host inflammatory reaction.

In a second, shorter portion of his paper, the author reviewed the concept of osteogenic induction, a term used to indicate an interaction between intrinsic and extrinsic factors of bone and reactive connective-tissue cells, which causes their transformation into bone-forming cells. He then described his experiments with cell-free extracts of heterogenous bone containing muco-polysaccharides closely resembling chondroitin sulphate A and C. One hundred and fifty-two specimens of bone extract impregnated in gelfoam and placed in the anterior chamber of the eye of the weanling and adult rat revealed one type of induced tissue which morphologically appeared in the early sacrifice periods to be cartilage. A second type of tissue, which was more highly differentiated, appeared to be morphologically similar to areas of osteoid or preosseous tissue in a fracture callus at the six-week period. Ninety-four control specimens did not show osteogenic activity at the implantation site.

**Suction Drainage of Orthopaedic Wounds.** Dr. Theodore R. Waugh [22] and Dr. Frank E. Stinchfield, in analyzing operative complications, noted the high incidence of hematomata with postoperative wound infections, particularly those due to *Staphylococcus pyogenes*. Therefore,

20. 139 Depew Street, Dumont, New Jersey.
21. 1011 Summit Avenue, Seattle 4, Washington.
22. 622 West 168th Street, New York 32, N.Y.

in those operations involving medullary bone, when complete hemostasis could not be achieved by meticulous technique, a suction catheter was used as the most efficient form of drainage.

These catheters were prepared by an inert and hydrophobic medical-grade of silicone rubber tubing, eighteen inches in length with an external diameter of one-quarter of an inch and an internal diameter of one-eighth of an inch, six one-eighth-inch holes being cut at one end. The catheters were placed deep in wounds, adjacent to the mold or femoral-head replacement in hip athroplasties, or on the bone grafts in hip or spine fusions. In general, this was adjacent to the source of bleeding. The end of the catheter was attached by sterile interconnecting tubing to one of the several available suction sources. The drainage was recorded with hematocrits of representative samples.

One hundred susceptible cases over a three-year period were included in the study. These were all operations performed in an area where hemostasis is difficult to achieve and a hematoma liable to develop.

There was a total of three complications, two of these being late sterile hematoseromata. One superficial wound infection followed a radical resection of the thigh for fibrosarcoma. This developed in the undrained part of the wound.

Seventeen positive catheter cultures suggest that an infection may be a relative matter and that the hematoma removal may be one factor in increasing the body resistance.

In general, it was found that the postoperative temperatures were lower, wound healing more satisfactory, and no interference with fracture healing or bone fusion could be demonstrated with catheter drainage.

Animal experimentation confirmed the removal of the hematoma with less tissue reaction and new-bone formation.

The authors concluded that orthopaedic wounds, where complete hemostasis cannot be achieved by ordinary techniques or where a potential dead space may exist, should be suction drained.

**Wound Sepsis in Orthopaedic Surgery.** Capt. George J. Schonholtz [23], Capt. Charles A. Borgia, and Col. John D. Blair, to test the effectiveness of postoperative prophylactic antibiotics in orthopaedic surgery, studied 331 non-infected surgical candidates at Walter Reed General Hospital over a twelve-month period. On the basis of their hospital register numbers, the patients were divided at random into control and experimental groups. One hundred and fifty-nine patients received no antibiotics postoperatively, whereas 172 received chloramphenicol. A two to four-gram dose, based on the patient's weight, was administered for ten days after operation. Statistical analysis revealed that both the control and the experimental group were comparable regarding magnitude and type of surgery, age, and sex. Classification of a wound as infected was based solely on positive bacteriological evidence. There was a direct relationship between the duration and the magnitude of surgery, the presence of hematoma, and subsequent wound infection.

The postoperative wound-infection rate for the group receiving no antibiotics was 3.8 per cent, whereas that for the group receiving chloramphenicol prophylactically was 6.4 per cent. Based on the evidence accumulated in this and related studies, it appears that prophylactic antibiotics double the postoperative wound-infection rate and increase the incidence of systemic infectious complications as well. Their use is contra-indicated in orthopaedic surgery.

**Spine Tuberculosis in Adults Treated without Surgical Fusion.** Dr. Barry Friedman [24] discussed eighty adult patients with tuberculosis of the spine who were treated without surgical fusion by a prolonged course of anti-tuberculosis drugs, bedrest, and, later, graduated activity with a back brace. Surgical evacuation of large abscesses was done only in selected instances.

Streptomycin, isoniazid, and para-aminosalicylic acid were used for an average of two and one-half years. Half of the patients in the series received all three drugs, whereas the remainder received para-aminosalicylic acid in combination with either streptomycin or isoniazid. Six deaths occurred in this series, four from lesions not related to tuberculosis, one in whom the treatment had failed, and one in a patient who failed to continue on medication. Fifteen patients had paraplegia.

With but one exception, all the vertebral lesions underwent repair, usually forming spontaneous osseous intervertebral bridges in the process. Abscesses and draining sinuses responded favorably. Follow-up extending to eleven years from the start of treatment showed that no arrested spine lesion had reactivated.

**Cervical Rib Syndrome. An Analysis of Thirteen Cases and Eighteen Operations.** Col. Earl W. Brannon [25] described the cervical rib syndrome as a definite clinical entity mani-

23. Martin Army Hospital, Fort Benning, Georgia.
24. 2460 Fairmount Boulevard, Cleveland Heights 6, Ohio.
25. 122 Sunnycrest Drive, San Antonio, Texas.

fested by predominantly local and neurogenic symptoms. He said that the anomalous rib acts as the primary compression factor; the scalene muscles play a secondary but significant role. Symptoms are more prevalent in women than in men and usually become manifest during the third or fourth decades of life.

Chronic cases which do not respond favorably to conservative treatment are amenable to relief by adequate surgical intervention. Operation should include total rib resection, excision of fibrotendinous bands, and section of the scalenus anticus and, perhaps, scalenus medius muscles, if best results are to be expected.

In the author's series of eight female and five male patients, the most common complaint was neck, shoulder, and arm pain. The pain was sharp or dull and of varying intensity, depending on the extent of normal activities. Examination showed fullness and tenderness in the supraclavicular region. Palpation over the anomalous rib elicited sharp pain which usually extended down the ulnar course of the extremity to the hand. All patients had some degree of numbness and tingling, especially in the ring and little fingers.

Eighteen operations were performed on the thirteen patients. In most patients the anomalous rib or fibrotendinous band was the primary factor that accounted for pressure or tension on the neurovascular elements. Nine patients experienced dramatic relief of pain immediately after surgery. None had complications or sequelae of permanent significance.

**Shoulder Fusions.** Dr. Virgil R. May, Jr.[26], presented fourteen case reports of patients who had had shoulder fusion. Eleven shoulders were fused because of residual weakness after poliomyelitis, one for brachial plexus paralysis, one for a bone cyst of the head of the humerus, and one for an old fracture-dislocation of the humeral head with pericapsular calcification. The author discussed the actions of muscles of the shoulder and noted the importance of the trapezius and serratus anterior, which must be fair to normal to make shoulder fusion effective.

Although the range of motion is limited after fusion, arthrodesis is superior to other operations for flail shoulder. The author stated that in his experience, transplantation of muscles about the glenohumeral joint had not been successful, especially if the deltoid was completely paralyzed.

Dr. May also stressed the importance of a good plaster spica cast, including both shoulders, to maintain the fusion position for three months. The involved arm should be placed in about 60 degrees of elevation, 25 degrees of forward flexion, and external rotation of about 40 degrees to the horizontal plane. The author used a wood screw to help immobilize the glenohumeral joint. He rated his results as five *excellent*, eight *good*, and one *fair*.

**Motor Paralysis of the Limbs in Herpes Zoster.** Dr. B. David Grant[27] and Dr. Carter R. Rowe said that although herpes zoster, or shingles, is not discussed in the orthopaedic literature it is, nevertheless, relevant to orthopaedic surgery. Its painful prodromal phase may lead to misdiagnoses, and lower motor-neuron paralyses in the limbs may occasionally occur. Since 1866, when the first account of motor involvement was described, there have been reports in the literature on forty-two patients with motor paralysis of the extremities, thirty of the upper extremity and twelve of the lower extremity.

The authors' interest in the condition was stimulated by a patient who complained of severe leg pain, followed within a few days by a herpetic rash, and subsequently by paralysis of the right quadriceps. This sequence of events is usual but not invariable.

They reviewed 101 consecutive patients with a diagnosis of herpes zoster who were admitted to the Massachusetts General Hospital over a ten-year period either for observation or treatment, or in whom the disease was an incidental finding when the patients were under treatment for another condition. Of the 101 cases of herpes zoster, twenty-four involved the limbs, and of these, five patients had lower motor-neuron paralysis (two of the upper extremity and three of the lower extremity). The majority of the patients reviewed were between the ages of fifty and eighty years. The case histories of the five patients with motor paralysis were given with a follow-up from three to nine years after the onset of the disease. Three patients had complete functional recovery. One patient had definite residual paralysis after three years, and one patient, reviewed nine years after the onset, with clinical motor weakness, was found to have a normal electromyographic response. An electromyogram done nine years previously showed weakness corresponding with the clinical picture.

The authors found in all the patients studied that the segments involved by motor paralysis corresponded approximately to the area of the herpetic rash on the same side, although other re-

26. 2222 Monument Avenue, Richmond 20, Virginia.
27. 721 Huntington Avenue, Boston 15, Massachusetts.

ports showed occasional variation. From a review of all previously published cases and their own, Dr. Grant and Dr. Rowe found that a good functional recovery may occur in 75 per cent of the patients.

The pathology of herpes zoster was reviewed and it was noted that its causative virus was identical with that of varicella. The histological picture that distinguishes herpes zoster from other pathological conditions was found to be: (1) ganglionitis marked by necrosis of all or part of the posterior root ganglion; (2) poliomyelitis distinguished from anterior poliomyelitis by its unilaterality, segmental localization, and greater involvement of the posterior horn, root, and spinal ganglion; (3) mild localized leptomeningitis; and (4) true peripheral mononeuritis.

The authors believe that the condition occurs more frequently than had hitherto been thought, and, if a diligent search in herpes zoster were made, clinical and subclinical pareses would be found more often.

**Radical Amputations of the Extremities for the Curative and Palliative Treatment of Malignant Neoplasm.** Dr. Robert W. Bailey [28] and Dr. David B. Stevens conducted a long-term study (1946 to 1959) at the University of Michigan Medical Center of thirty-four patients with malignant neoplasms of the extremities who were treated by ablation of the upper or lower extremity by forequarter resection, disarticulation of the hip, or hemipelvectomy. Two of these patients were so treated to palliate painful metastatic lesions. Of the thirty-two treated for primary malignant tumors in the extremities, fourteen are still alive. Of the ten patients who had disarticulation of the hip, only one has survived longer than five years and another still survives two and a half years after operation. Of sixteen patients who underwent hemipelvectomy, four have survived more than five years and three more are still alive less than five years after operation. Of eight patients who had forequarter amputations, three have survived longer than five years and three more are alive less than five years after operation.

**The Surgical Treatment of Coxa Vara in Childhood.** Dr. Oscar Scaglietti [29] said that the various forms of surgical treatment used so far for coxa vara have not offered a completely satisfactory solution. The main problems are the abnormal angle of inclination and shortness of the femoral neck; both these changes have a marked influence on the function of the hip joint.

To be really effective, any treatment must, in the author's opinion, restore a physiological angle and adequate length of the femoral neck.

Two years ago Dr. Scaglietti developed a method of surgical treatment which restores the normal anatomical relationship of the neck and the proximal metaphysis of the femur. The method includes the following steps: (1) a transverse subtrochanteric osteotomy; (2) the insertion of two long screws, one into the apex of the greater trochanter and the other into the diaphysis below the osteotomy; (3) rotation of the proximal fragment downward to restore a normal angle of the femoral neck, using the screws as levers and holding devices to effect and maintain the change of position; and (4) in patients with a varus deformity of over 90 degrees and a markedly shortened femoral neck, distal displacement of the greater trochanter to lengthen the femoral neck and restore normal tension of the pelvitrochanteric muscles.

The details of the surgical technique and the results in the series of patients treated with this method were illustrated by a color and sound movie.

**Congenital Skeletal Deficiencies of the Extremities, Their Classification and Fundamentals of Treatment.** Dr. Cameron B. Hall [30], Dr. Milo B. Brooks, and Jeannine F. Dennis, O.T.R., applied the classification of congenital skeletal deficiencies of the extremities devised by O'Rahilly and Frantz to 170 children treated at the University of California Medical Center at Los Angeles. It provided a good basis for surgical and prosthetic treatment, as well as an efficient aid to studies of incidence. Each of the two groups of defects—terminal and intercalary—were further divided into transverse and paraxial subgroups. Cases in each of the four resulting categories were discussed by the authors and the methods for treatment were summarized. They said that although the series is too small to detect etiological factors, gestational and hereditary influences were strongly suspected in certain types of congenital skeletal deficiencies.

The early prosthetic restoration of parts was emphasized, especially when the lower extremity is involved. The newer developments in prosthetics are especially helpful. When other series are similarly classified, perhaps the cumulative data will yield etiological as well as other information of value.

28. 1405 East Ann Street, Ann Arbor, Michigan.
29. Istituto Ortopedico Toscano, Florence, Italy.
30. 11600 Wilshire Boulevard, Los Angeles 25, California.

**Amputation and Prosthesis as Definitive Treatment in Congenital Absence of the Fibula.** Dr. Leon M. Kruger [31] and Dr. Richard D. Talbott. (J. Bone and Joint Surg., **43-A**: 625–642, July 1961.)

**Dysgenesis of the Proximal Femur and Its Surgical Management.** Dr. Philip D. Wilson, Jr. [32], and Dr. Harlan C. Amstutz believe that coxa vara is a result of many acquired and congenital disturbances and that its differential diagnosis is important to effect proper surgical management. The pathogenesis, prognosis, and treatment of three seemingly related groups—forty cases of congenital short femur, congenital bowed femur, and congenital coxa vara—were discussed by the authors. The patients all manifested coxa vara and ossification disturbances of unknown etiology. Those with congenital short femur manifested marked shortening, severe dissolution of the femoral neck, and a stunted dysplastic proximally tapered shaft. Conservative management was emphasized, with surgery reserved for individual prosthetic fitting and cosmetic needs.

Patients with congenital bowed femur exhibited moderate shortening, lateral subtrochanteric bowing, medial subtrochanteric sclerosis, and minimum varus progression. A strikingly poor prognostic sign in this group was that of progressive dysplasia of the femoral head and acetabulum, contra-indicating late corrective osteotomy.

*Prognosis* of congenital coxa vara (infantile, cervical, or developmental) varied with the width and direction of the linear neck defect. Severe disturbances exhibited marked varus progression and late dysplasia. In those, early radical osteotomy is indicated; however, it may be delayed with less radical correction in those with mild deformity and mild varus progression.

The authors also discussed surgical management with interlocking intertrochanteric osteotomy.

**The Treatment of Scoliosis (Risser Localizer Cast and Spine Fusion).** Dr. Charles N. Pease [33], Dr. George H. Millington, and Dr. Leonard A. Shepanek reviewed 115 children (average age, twelve years) who were treated by Risser localizer casts followed by spine fusion. Fifty-one patients had one cast applied, forty-two had two, and twenty-two had multiple casts. The spines were fused through a window in the cast: fifty-seven in a one-stage procedure, fifty-one in a two-stage procedure, and two in a three-stage procedure. Five patients had coexistent spondylolisthesis and ten had congenital heart disease. The children were allowed to walk on the average four days after operation. Complications were minimum. Pseudarthroses occurred in 17 per cent, which were fused at a second operation. The over-all results were very satisfactory.

**Scoliosis Correction with Risser Ambulatory Traction Jackets. A Five-Year Report.** Dr. Jacob J. Graham [34] said that during the past five years 312 ambulatory corrective traction jackets of the Risser localizer type were applied to sixty-six patients with various types of scoliosis, predominantly idiopathic, in the Scoliosis Clinic of the Hospital for Joint Diseases. The patients were divided into mild, moderate, and severe groups according to the severity of the curve as measured by the Risser-Ferguson method. In the eight patients with mild curves (0 to 20 degrees) the localizer cast was used without fusion, with no permanent improvement in any. In the thirty patients with moderate curves (25 to 40 degrees) the average correction obtained was 59.4 per cent in the erect and 67.2 per cent in the recumbent position. These results compared well with the correction reported in other series with turnbuckle and localizer casts. In the twenty-eight patients with severe curves (45 degrees and over) the average correction obtained was 47 per cent in the erect and 56 per cent in the recumbent position. Again these results compared well with the correction reported in other series. Spine fusions were performed on thirty-eight patients in the moderate and severe groups, with an over-all pseudarthrosis rate of 39.5 per cent. These thirty-eight patients were treated without bone grafts, with homogenous bank-bone grafts, and with autogenous-iliac grafts. In the later cases, only autogenous-iliac grafts were used, and the pseudarthrosis rate was significantly less. Most of the pseudarthroses were successfully repaired, so that the final percentage of unsuccessful fusions was 13.3. In the seventeen patients in the moderate group with spine fusions, the final average net correction was 39.6 per cent. In the twenty-one patients in the severe group with spine fusions, the final average net correction was 30.1 per cent. The results obtained without fusion in the twenty-eight patients in the mild, moderate, and severe groups have been disappointing; they tend to preclude this type of treatment except in the very young. It would appear that Risser's ambulatory traction localizer jacket is just as effective in the correction and maintenance of correction in scoliosis as other methods in general use. In all patients treated with spine fusion in conjunction with this plaster jacket there was increase in length of the torso, improvement in the

31. 516 Carew Street, Springfield 4, Massachusetts.
32. 535 East 70th Street, New York 21, N.Y.
33. 104 South Michigan Avenue, Chicago 3, Illinois.
34. 45 East 72nd Street, New York 21, N.Y.

rotational deformities, and better gross alignment of the trunk, without loss of compensation. The method does entail considerable labor and requires rather meticulous attention to detail since pressure sores have been a major complication. Although the pseudarthrosis rate has been alarmingly high in this series it would appear that, with the exclusive use of autogenous iliac-bone grafts, this high rate can be decreased considerably. This would suggest that being erect and walking in this jacket were not the causes of pseudoarthrosis. The ambulatory treatment has obvious advantages for the patient and makes it possible, with only a limited number of hospitals, to treat a large number of patients.

**Surgery of the Equinovarus Foot Utilizing Tarsometatarsal Ligament Release and Other Soft-Tissue Procedures.** Dr. J. Leonard Goldner [35].

**Traumatic Dislocations of the Hip in Children.** Dr. F. James Funk, Jr.[36], analyzed forty cases of traumatic dislocation of the hip in children. He presented a collected series consisting of his own patients and cases contributed by friends and associates, many of whom were members of the Piedmont Orthopaedic Society. The patients' ages ranged from two to fourteen years. Twenty of the forty cases had follow-ups for four or more years. The study demonstrated that, in general, in children under the age of six, dislocations resulted from relatively trivial injuries. In this age group, reduction was easy, and, with only one exception, the end results were uniformly good. In children between the ages of six and ten, relatively greater trauma was necessary to cause the injury, and in several instances there were late complications consisting of degenerative or vascular changes. Open reductions were necessary in three patients. In older children, eleven to fourteen years, severe trauma caused the dislocation; closed reductions were possible in all these children, and the end results, as a rule, were good.

Three patients suffered anterior dislocations. In nine patients reduction was delayed more than twenty-four hours, and, except for two of the younger children, all the children who could be closely followed demonstrated abnormal changes by roentgenogram. Three patients required open reduction, and completely normal hips did not result in any of them. When the results were studied and the predictably poor patients with delayed reductions and open surgery were eliminated, there appeared to be some correlation between early weight-bearing and delayed degenerative or aseptic changes.

The conclusions reached from this study were that in small children traumatic dislocations occur with minimum trauma, as a rule can be reduced easily, and, except in rare instances, a perfect hip is the end result. Older children require considerably more trauma to cause dislocation and a significant percentage will have roentgenographic changes. It was the feeling of the author that this study emphasized the need for early reduction and he recommended that children over the age of six should avoid weight-bearing for a period of three months after reduction.

**Lumbosacral Fusion by Bilateral Lateral Technique.** Dr. Keith McElroy [37].

**Posterolateral Fusion of the Lumbosacral Spine.** Dr. George Truchly [38] and Dr. Walter A.L. Thompson presented their modification of the original Watkins technique and the end-result study of forty-three consecutive operations performed during the last six years. The modification consisted in utilizing two separate incisions instead of one large U-shaped incision, detaching the sacrospinalis origin from the iliac crest with a sliver of bone to facilitate closure, and using multiple slivers of bone obtained from the ilium as graft material instead of one solid block. All forty-three patients reporting for the follow-up study were personally examined by one of the authors. Results of biplane bending roentgenograms and clinical evaluation were utilized for rating. The operations were performed on twenty-two patients with an unstable spine following laminectomy, fifteen patients with primary unstable spine, and six patients with spondylolisthesis. This procedure was originally regarded as a salvage operation, and a great majority of patients had multiple previous surgical interventions. Two patients in this study had only one segment, fifth lumbar to first sacral, fused. Both patients showed solid fusion. Of the remaining forty-one patients, when a fusion of two segments, fourth to fifth lumbar and fifth lumbar to first sacral, was attempted, solid fusion occurred in thirty-eight instances. Of three failures, two patients showed motion only at the fourth to fifth lumbar segment, and one patient had non-union at both segments. Postoperative complications included paralytic ileus, wound hematoma, infection, and thrombophlebitis; these were discussed in detail. The advantages of this operation were listed as: lower rate of non-union (7.3 per

35. Duke University Medical Center, Durham, North Carolina.
36. 1938 Peachtree Road, N.W., Atlanta 9, Georgia.
37. 180 Fort Washington Avenue, New York 32, N.Y.
38. 480 First Avenue, New York 10, N.Y.

ent in the series); no need of internal fixation of the bone graft; easy fitting of the graft; facility of fusion after laminectomy since hypertrophy of the graft cannot encroach upon the epidural space which can happen in posterior fusion; ease of exploration of the epidural space at a later date, if necessary, as there is no fusion plate over the lamina to interfere with laminectomy. Longer operating time and greater loss of blood were considered the disadvantages of the procedure. The authors felt, however, that the advantages outweighed the disadvantages. It was their impression that despite the modest number of cases in this series, the conclusion was warranted that this operation considerably reduced the incidence of non-union and should be seriously considered in cases of multiple unsuccessful attempts at fusion of the lumbosacral spine.

The following list of applicants was approved by the Executive Committee for Active Fellowship:

Richard H. Allen, Battle Creek, Michigan
Gordon W. D. Armstrong, Ottawa, Ontario, Canada
Samuel W. Atkins, Jr., Danville, Virginia
Bert P. Austin, Utica, New York
George W. Bagby, Spokane, Washington
Maxwell B. Bardenstein, Detroit, Michigan
John L. Barnard, Jr., Kansas City, Missouri
Robert M. Barnett, Minneapolis, Minnesota
Comdr. Jaime M. Benavides, M.C., U.S.N.
E. Leo Bennish, Detroit, Michigan
Anthony J. Bianco, Jr., Rochester, Minnesota
Harry H. Bleecker, Jr., Arcadia, California
Floyd E. Bliven, Jr., Augusta, Georgia
Luman W. Bromley, Fort Wayne, Indiana
Maj. Richard S. Bryan, M.C., U.S.A.F.
Joseph F. Buckley, New Bedford, Massachusetts
Paul Campbell, Portland, Oregon
Robert E. Carlton, Colorado Springs, Colorado
Peter A. Casagrande, Buffalo, Illinois
Lt. Col. James D. Caskie, M.C., U.S.A.
Roy B. Coffey, Salina, Kansas
Harry Lee Collins, Jr., Jacksonville, Florida
Russell F. Compton, Pasadena, California
Lee J. Cordrey, Tampa, Florida
Adrian R. Coren, Levittown, New York
John W. Cortner, Tucson, Arizona
Richard M. Cronin, River Forest, Illinois
Lewis E. Curlee, Concord, North Carolina
A. Ross Davis, Houston, Texas
Thomas L. DeLorme, Boston, Massachusetts
James A. Devlin, Midland, Michigan
George W. Deyoe, Modesto, California
William C. Dunckel, Jr., San Jose, California
John W. Elliott, Springfield, Ohio
Carl B. Eshelman, Shillington, Pennsylvania
Robert H. Fain, Houston, Texas
Edward L. Farrar, Jr., Orlando, Florida
Joseph H. Field, San Jose, California
Ray Fife, Phoenix, Arizona
Robert VanDusen Finnesey, South Orange, New Jersey
Delbert L. Fischer, Lorain, Ohio
Alan Fixler, San Francisco, California
Paul Florez, Cincinnati, Ohio
Robert R. Giebink, Sioux Falls, South Dakota
Edward P. Gillette, Jr., Sandusky, Ohio
Murray R. Glickman, Philadelphia, Pennsylvania
Capt. Dana D. Goldthwaite, M.C., U.S.N.
John J. Greenler, Lynn, Massachusetts
Ledford G. Gregory, Miami Springs, Florida
John B. Griffin, Chicago, Illinois
Paul O. Gustafson, Minneapolis, Minnesota
Robert A. Haliburton, Windsor, Ontario, Canada
John Harder, Portland, Oregon
James W. Harkess, Augusta, Georgia
William K. Harryman, Jr., Hackensack, New Jersey
David N. Hawkins, Knoxville, Tennessee
John W. Hayden, La Crosse, Wisconsin
Philip G. Hersbberger, Fort Wayne, Indiana
Donald K. Hester, Santa Monica, California
Mortimer Housberg, Farmingdale, New York
Francis M. Howard, Chicago, Illinois
Capt. John W. Howard, M.C., U.S.N.

Andrew G. Hudacek, Morristown, New Jersey
Albert S. Jacknow, Pontiac, Michigan
Arthur M. Jansa, Houston, Texas
Irvine G. Jordan, Jr., Albuquerque, New Mexico
Manny J. Karbelnig, Huntington Park, California
John E. Keith, Spartanburg, South Carolina
Peter I. Kenmore, Brentwood, Maryland
William T. Kernahan, Jr., Chicago, Illinois
Robert C. Keys, South Norwalk, Connecticut
Thomas E. Kilkenny, Eau Claire, Wisconsin
Hobart E. Klaaren, Dayton, Ohio
Bernard Krakauer, Detroit, Michigan
Bertram M. Kummel, Morristown, New Jersey
Herbert E. Lane, Jr., Falls Church, Virginia
Livius L. Lankford, Dallas, Texas
Thomas S. Lastrapes, Marion, Ohio
Robert B. Lea, Elgin, Illinois
Clarence M. Leary, Stockton, California
Roy H. Ledbetter, Jr., Monroe, Louisiana
Gwilym B. Lewis, Berkeley, California
Philip London, Philadelphia, Pennsylvania
Ralph Lusskin, New York, N. Y.
Forrest N. Maddix, Jr., Wellesley Hills, Massachusetts
Edwin R. Maier, Oklahoma City, Oklahoma
Irving G. Manning, Islip Terrace, New York
J. John Manson, Redondo Beach, California
Leonard Marmor, Los Angeles, California
Edwin H. Martinat, Greenville, South Carolina
Arthur L. Messinger, Sunnyvale, California
Lt. Col. Charles W. Metz, Jr., M.C., U.S.A.
William J. Mills, Jr., Anchorage, Alaska
Richard M. McAtee, Los Angeles, California
Ward A. McClanahan, Wichita, Kansas
William J. McHolick, Eugene, Oregon
Robert R. McKnight, Jr., Augusta, Georgia
John J. McLeod, Jr., Grand Forks, North Dakota
William B. McNamee, Upper Derby, Pennsylvania
Capt. James E. Nixon, M.C., U.S.A.F.
Kenneth J. O'Brien, Brooklyn, New York
Byron J. Park, Richmond, Indiana
David W. Patch, Syracuse, New York
Marshall Pattullo, Grand Rapids, Michigan
Hubert S. Pearlman, Brooklyn, New York
Maurice F. Perll, Kansas City, Missouri
Richard A. Pettee, Richland, Washington
Jack H. Phillips, Natchez, Mississippi
Ralph Pietrobono, San Jose, California
Norman L. Portello, Pleasant Hill, California
Edward K. Rath, Milwaukee, Wisconsin
Wiley L. Renshaw, Van Nuys, California
Jack L. Robbins, Evanston, Illinois
Lorne A. Rolston, Encino, California
Herbert S. Rosenthal, Paterson, New Jersey
Raymond S. Roy, West Palm Beach, Florida
Theodore J. Rusnack, Glen Cove, New York
Fred P. Sage, Memphis, Tennessee
Glenn A. Sanford, Bloomfield Hills, Michigan
Anthony J. Santoro, Paterson, New Jersey
Thomas B. Scanlon, Jr., San Francisco, California
Francis J. Schiller, Whittier, California
Erwin R. Schmidt, Jr., Philadelphia, Pennsylvania
Francis B. Schuler, Portland, Oregon
Joseph C. Serletti, Jamaica, New York
Lee W. Shaffer, Roanoke, Virginia
Emmet Shannon, Lubbock, Texas
John D. Sherrill, Jr., Birmingham, Alabama
John L. Shively, Lafayette, Indiana
H. Gerard Siek, Jr., Clearwater, Florida
Anthony John Smith, Coos Bay, Oregon
Arthur Kent Smith, Fall River, Massachusetts
Richard Draper Smith, Lubbock, Texas
Harold E. Snedden, Sandusky, Ohio
Joseph J. Sofranec, Jr., Youngstown, Ohio
Morton Spinner, Brooklyn, New York
Warren G. Stamp, St. Louis, Missouri
Archie C. Stanton, Newport News, Virginia
William M. Steele, Traverse City, Michigan

Jose F. Suarez-Alvarez, Santurce, Puerto Rico
Thomas F. Sullivan, Jr., Pittsfield, Massachusetts
F. Nelson Suma, Rockford, Illinois
Maj. Robert L. Sundre, M.C., U.S.A.
George G. Susat, Irving, Texas
Howard J. Sweeney, Evanston, Illinois
Ernest D. Szabados, Independence, Missouri
Richard H. Tapogna, Springfield, Ohio
Joseph C. Tedesco, Buffalo, New York
William A. Terheyden, Miami, Florida
Francis H. Tonkonow, Meriden, Connecticut
William R. Torgerson, Jr., Grand Rapids, Michigan
William R. Tregoning, Boise, Idaho
Richard M. Ulery, Santa Monica, California
Earl E. VanDerwerker, Hartford, Connecticut
George H. Vogt, Madison, Wisconsin
F. William Wagner, Jr., Whittier, California
Jack M. Walker, Muncie, Indiana
Harold B. Warren, Lakewood, California
Jack B. Watkins, Spokane, Washington
George S. Whatley, Columbus, Georgia
Hilton R. Wilhite, Victoria, Texas
James B. Wray, Syracuse, New York
Richard N. Wrenn, Charlotte, North Carolina
John L. Wright, Bloomington, Illinois
Owen W. Young, Tonawanda, New York
Robert William Young, Orlando, Florida
Lt. Col Wilhelm A. Zuelzer, M.C., U.S.A.

## CORRECTIONS

An error occurred in Dr. Chuinard's discussion of the paper by Dr. Sherman S. Coleman "Treatment of Congenital Dysplasia of the Hip and Its Sequelae" as abstracted in Proceedings of the Western Orthopedic Association, J. Bone and Joint Surg., **43-A:** 316, March 1961. The last sentence of Dr. Chuinard's discussion should read "Subtrochanteric osteotomy has been helpful in correcting anteversion and producing coxa vara, which aids in maintaining reduction". The previous notice on page 622 of the June issue of *The Journal* should be disregarded.

An error occurred in the article "Metaphyseal Cortical Defects in the Tubular Bones of Growing Children" by Samuel Selby, M.R.C.S., J. Bone and Joint Surg., **43-A:** 395–400, Apr. 1961. The last sentence of the next to the last paragraph before the center heading *Conclusion* on page 399 should read "These defects, therefore, lasted longer than those in the series of Sontag and Pyle, in which defects were observed to persist for an average of twenty-nine months".

# News Notes

The Annual Meeting of the **Western Orthopedic Association** will be held at the Statler-Hilton Hotel, Dallas, Texas, October 17 through 21, 1961, under the Presidency of Dr. Marvin P. Knight.

---

A meeting of the **Texas Orthopaedic Association** was held in Galveston, Texas, on April 24, 1961, in conjunction with the meeting of the Texas Medical Association. The following program was presented:

Pollicization of the Index Finger: R. A. Murray, M.D., Temple;

Avulsion Fractures of the Fibula, a Cause of Ankle Instability: Col. John J. Brennan, M.C., El Paso;

The Treatment of Chronic Stasis Ulcer: Harvey R. Butcher, M.D., St. Louis, Missouri;

Experimental Production of Pseudarthrosis in Dog Femora: Bruce M. Cameron, M.D., Houston;

Non-Union of Long Bones: Edwin F. Cave, M.D., Boston, Massachusetts;

President's Address: I. S. McReynolds, M.D., Houston;

The Stiff and Painful Shoulder: T. B. Quigley, M.D., Boston, Massachusetts;

Experience with Anterior Cervical Spine Fusion: C. F. Gregory, M.D., and W. Kemp Clark, M.D., Dallas;

Herniated Lumbar Intervertebral Discs: P. L. Day, M.D., San Antonio;

Spine Instrumentation in the Management of Scoliosis (Motion Picture): Paul R. Harrington, M.D., Houston.

Robert A. Murray, M.D., of Temple, was elected President for the ensuing year; Margaret Watkins, M.D., Dallas, is Secretary.

---

A three-day **International Symposium on Bone** will be held at the University of California Medical Center, San Francisco, California, on October 7, 8, and 9, 1961. A distinguished international group of scientists will present the results of current research and their clinical application. Subjects on which informed opinions differ, such as the causes and treatment of osteoporosis, will be presented. New tests of parathyroid function will be discussed and the use of radioactive tracers to understand skeletal mineral turnover will be thoroughly explored. Further information and application for enrollment may be obtained by applying to Seymour M. Farber, M.D., Assistant Dean, University of California Medical Center, San Francisco 22, California.

---

A **Continuation Course in Orthopaedics for Orthopaedic Surgeons (Hand Surgery)** will be held at the Center for Continuation Study, University of Minnesota, Minneapolis, Minnesota, November 16, 17, and 18, 1961. Information and applications may be obtained from W. Albert Sullivan, Jr., M.D., Director, Department of Continuation Medical Education, The Medical School, University of Minnesota, Minneapolis 14, Minnesota.

---

A postgraduate course on **Injury of the Joints of the Upper Extremity** will be given during the Clinical Congress of the American College of Surgeons in Chicago, October 2 to 6, 1961. Dr. Sam W. Banks, Chicago, is Chairman.

---

A **Memorial Lectureship** honoring **Dr. George B. Packard, Sr.,** Colorado's first orthopaedic surgeon, has been established. It is jointly supported by the Rocky Mountain Orthopaedic Society and the Division of Orthopaedics of the University of Colorado School of Medicine.

The first lecture was given by Dr. C. Howard Hatcher, Chairman of the Department of Orthopaedics, Stanford University School of Medicine, who spoke on Regional Resection for Bone Sarcoma.

---

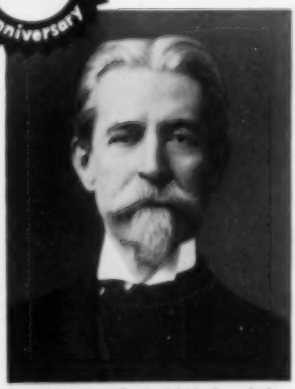
Columbia University College of Physicians and Surgeons is sponsoring a three-day symposium entitled **Basic Problems in Neoplastic Disease** to be held on March 12, 13, and 14, 1962. This symposium will commemorate the Fiftieth Anniversary of the Institute of Cancer Research at Columbia University and the Tenth Anniversary of its associated clinical facility, The Francis Delafield Hospital. The symposium is open without fee to all interested workers in the field of neoplastic disease. For details concerning the meeting, including application to attend sessions, write to the Institute for Cancer Research, Columbia University College of Physicians and Surgeons, 630 West 168th Street, New York 32, N. Y.

# 100 YEARS *of service in the prosthetics field*

Hanger PROSTHESES

Centennial Hanger Anniversary

**The year of 1961 marks one hundred years of service in the field of prosthetics for the Hanger Organization. Over these one hundred years the name Hanger has become synonymous with prosthetic appliances.**



J. E. Hanger, who in 1861, founded the Hanger Organization

• There are over 50,000 wearers of Hanger Prostheses—more than any other make • Complete line of arm and leg prostheses for all types of amputations • Constantly improved through research • All Hanger offices offer the services of one or more Certified Prosthetists • Advanced college courses given Hanger Prosthetists • Nearly 40 offices in principal cities.

May we put our one hundred years of experience to work for you?

Hanger PROSTHESES

**EASTERN REGION:**

BALTIMORE 1, MD.
BOSTON 15, MASS.
CHARLESTON 1, W. VA.
NEW YORK 11, N. Y.
PHILADELPHIA 7, PA.
RALEIGH, N. C.
RICHMOND 19, VA.
ROANOKE 12, VA.
WASHINGTON 13, D. C.

**MIDWESTERN REGION:**

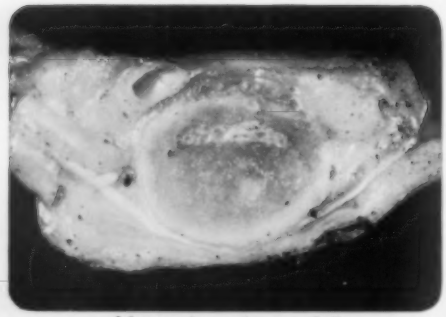
CHICAGO 5, ILL.
CINCINNATI 29, OHIO
DALLAS 1, TEXAS
EVANSVILLE, IND.
FORT WAYNE, IND.
INDIANAPOLIS 2, IND.
OKLAHOMA CITY 3, OKLA.
PEORIA 4, ILL.
ST. LOUIS 66, MO.

**CENTRAL REGION:**

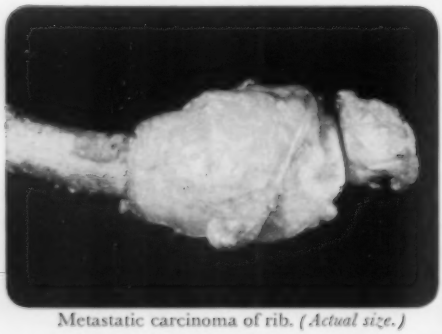
COLUMBUS 8, OHIO
PITTSBURGH 1, PA.

**SOUTHEASTERN REGION:**

ATLANTA 9, GA.
BIRMINGHAM 1, ALA.
COLUMBIA 1, S. C.
JACKSONVILLE, FLA.
LAFAYETTE, LA.
MIAMI 37, FLA.
MOBILE, ALA.
MONTGOMERY, ALA.
NASHVILLE 5, TENN.
NEW ORLEANS 19, LA.
ORLANDO, FLA.
SAVANNAH, GA.
ST. PETERSBURG, FLA.
TAMPA 2, FLA.
WEST PALM BEACH, FLA.

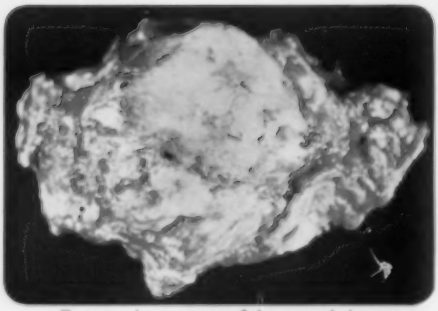


Metastatic carcinoma of rib.
*(Three times actual size.)*



Metastatic carcinoma of rib. *(Actual size.)*

# Shoot it—as you see it—with this new Kodak Retina Reflex III Camera



Osteogenic sarcoma of the manubrium.
*(Two-thirds actual size.)*

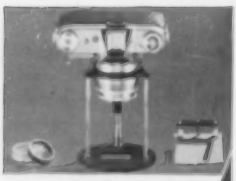
Three simple steps with a Kodak Retina Reflex III Camera . . . that's all!

*First:* You view the subject right side up, laterally correct . . . *in other words, compose the picture.*

*Next:* By means of a clear, split-image precision rangefinder, or on a ground glass so fine you hardly realize it's there . . . *you make sure the picture will be sharp.*

*And finally:* Without taking camera from the eye, you simply center the exposure control needle between two brackets, *thus assure correct exposure.*

Simple? Yes. And tremendously efficient with a range of features that makes the Kodak Retina Reflex III unique among today's fine cameras. Price, with 50mm *f*/2.8 lens, less than $215.



The Retina System includes a wide range of photo aids including a precise 1:1 kit for same-size copying and a kit for photomicrography that positions Kodak Retina Reflex III over the microscope eyepiece.

*Price is subject to change without notice.*

For further information, see your Kodak photographic dealer, or write:
**EASTMAN KODAK COMPANY, *Medical Division*, Rochester 4, N.Y.**
*Serving medical progress through Photography and Radiography*

Kodak
TRADE MARK

PERFECT MATES

When a child needs one shoe size for one foot and a different size for the other, Child Life Mismates are the "perfect mates" — for comfort, for style and for fit.

. . . And Herbst's Mismate Service from stock means the end of six-weeks waits. When your prescription requires urgency Mismates will be shipped the same day the order is received — and they are sent Special Delivery.

Child Life SHOES

MISMATE SERVICE

Write: Carlton Lincoln, HERBST SHOE MANUFACTURING CO., Box 2005, Milwaukee 1, Wisconsin

To serve your complete needs in
ORTHOPEDIC, PROSTHETIC
and SURGICAL APPLIANCES

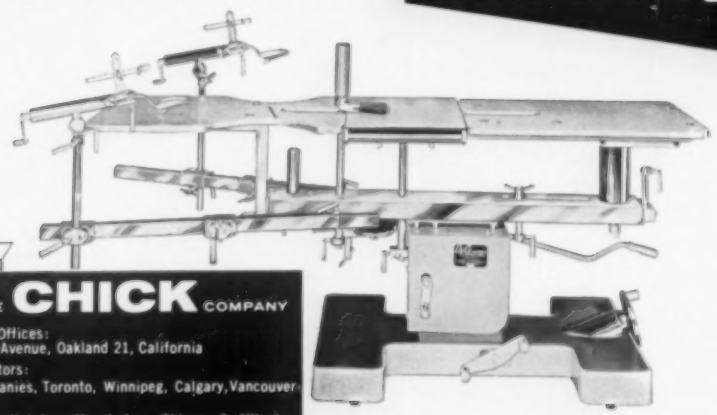
**house of BIDWELL inc.**

535 N. 27th Street
Milwaukee 8, Wis.

1134 Regent St.
Madison, Wisconsin

**Flexibility Insures Maximum Efficiency**

Flexibility is the keynote of Chick DVHI Orthopedic and Surgical Table. Featuring variable height, it employs a self-contained hydraulic unit with built-in safety factor. Table tilts laterally and offers Trendelenburg position of 15°, **reverse Trendelenburg of 7½°**. Other outstanding features include **new foot-locking device for positive table positioning** and carriage-mounted Chick Transverse Cassette Tunnel. DVHI is ideal for all Orthopedic surgery, most general surgery, and all cast work. Write today for information.



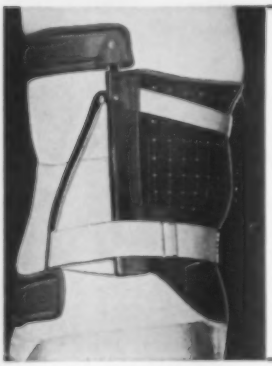
GILBERT HYDE **CHICK** COMPANY

Plant and Sales Offices:
821 - 75th Avenue, Oakland 21, California

Canadian Distributors:
The Stevens Companies, Toronto, Winnipeg, Calgary, Vancouver

Exporter:
J. D. Marshall International, Inc., Chicago 2, Illinois

Manufacturers and Distributors of
Hospital Orthopedic and Fracture Equipment



**The "ORIGINAL"**
**WILLIAMS lumbo-sacral flexion back brace—**
**designed by Dr. Paul C. Williams**

"To reduce the lumbo-sacral lordosis and thus lift the weight from the posterior vertebral structures. Permits free ant. flexion of the lumbar spine but prevents extension and lateral flexions."

Measurements

1. Chest (about 4" below nipple line)
2. Waist (at navel line)
3. Pelvic (½ distance between greater trochanter and crest of ilium)
4. Back (seventh cervical spinous process to the prominence of coccyx.)

Order filled at the request of members of the profession only

**MILLER BRACE COMPANY**

*(Established in Dallas since 1932)*

**3902 Gaston Avenue** **P.O. Box 7902** **Dallas, Texas**

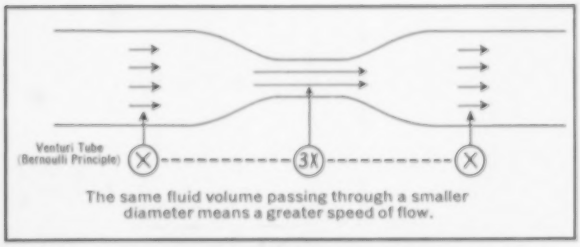
# T.E.D. anti-embolism stockings speed blood flow, help reduce fatalities due to pulmonary embolism!

## Accelerated blood velocity minimizes formation and incidence of clots

T.E.D. Anti-Embolism Stockings insure steady, uniform pressure of the lower leg, helping to speed the flow of blood.

It is reported that the majority of fatal pulmonary emboli cases originate with clots from the deep veins of the calf. T.E.D. Anti-Embolism Stockings counteract this by reducing the caliber of the veins enough to accelerate blood velocity and thus discourage thrombus formation.

T.E.D. Anti-Embolism Stockings maintain an over-all compression between 10 and 15 mm. of mercury—as you know, the ideal range in prophylaxis for thrombo-embolic disease. Application is so simple it can be handled even by a nurse's aid.




The same fluid volume passing through a smaller diameter means a greater speed of flow.

A constriction in a pipe increases the velocity of flow. The T.E.D. Anti-Embolism Stocking applies this principle, speeding the flow of blood in the lower leg where emboli most often get their start.

**Recent Literature on Thrombosis and Pulmonary Embolism**


1. Marino, D. J., and Fuchs, M.: Pathogenesis, Diagnosis, and Management of Thrombophlebitis, Geriat. 13:307 (May) 1958.

2. Houston, A. N., Roy, W. A., and Faust, R. A.: Thrombophlebitis of Superficial Abdominal Veins, J.A.M.A. 166:2158 (April 26) 1958.

3. Wilkins, R. W., Mixter, G., Jr.; Stanton, J. R., and Litter, J.: Elastic Stockings in the Prevention of Pulmonary Embolism, New England J. M. 246:360 (Mar. 6) 1952.

4. Judson, W. E.: Present Day Treatment of Congestive Heart Failure, The M. Clinics of N. America 35: 1333-1350 (Sept.) 1950.

5. Tidler, J.: Thrombo-Embolic Disorders, N. Carolina M. J. 18:65 (Feb.) 1957.

6. Allen, A. W.: Management of Thrombo-Embolic Disease in Surgical Patients, Surg., Gynec. and Obst. 96:107 (Jan.) 1953.

7. Foley, W. T., and Wright, I. S.: Medical Management of Thrombophlebitis, The Heart Bulletin 7:5 (Jan.-Feb.) 1958.

8. DeLaughter, G. D., Jr., Embolism, Pulmonary, in Conn., H. F., Current Therapy, Philadelphia, W. E. Saunders Co., 1958, P. 83.


**T.E.D.®**
**ANTI-EMBOLISM STOCKINGS**

THE KENDALL COMPANY
BAUER & BLACK DIVISION

FOR COMPLETE LITERATURE on Thrombo-Embolic prophylaxis using T. E. D. Anti-Embolism Stockings, fill in and mail this coupon to:

**The Kendall Company**
**Bauer & Black Division,**
**Dept. BJS-9**
**309 W. Jackson Blvd., Chicago 6, Illinois**

Name _____

Address _____

City _____ Zone _____ State _____

# boon to time-conscious doctors

***FREE informative booklets on child foot care to help you help your patients***

This 12-page factual booklet, "bare/foot facts", is cram full of answers thoughtful parents want to know about the all-important subject of youngsters' foot health. A supply of these booklets in your waiting room could very well provide answers to questions parents had thought of asking you . . . while they're waiting to see you! You save your valuable time and parents can attain valuable knowledge on children's foot health. It tells about such things as "foot exercises," "the wearing of sneakers," "can shoes be handed down?", and so very much more. For a sample copy and information on obtaining a free supply for your office, have your nurse mail this coupon today!

*Offered as a public service by*

Junior ARCH PRESERVER Shoes by MEDIC

**MEDIC Shoe Manufacturers, Inc.**
1212 Wood St., Philadelphia 7, Pa.
Gentlemen: Please send me a sample of the booklet, "bare/foot facts."
NAME_____
ADDRESS_____
CITY_____ ZONE_____ STATE_____

DESIGNED FOR COMFORT!

The TEARE ARM SLING

U.S. Pat. 2529677
Canada Pat. 485201

COMFORT SIZES FOR ALL!

*In White Cotton–adult, child and extra small child sizes*
*In Black Cotton and Plastic–adult size only*
TIME SAVING • ADAPTABLE • SCIENTIFIC
*Write for Nearest Distributor*

*Mfd. exclusively by*
**M. M. TEARE CO., INC.**
**Dept. JB, 209 Melrose Bldg., Buffalo 10, New York**

## *ACTIVE HAND and FINGER SPLINTS*

**Instruments for Hand Surgery and Treatment**

*AS DESIGNED BY*
Dr. STERLING BUNNELL
**Carried in stock for immediate delivery**

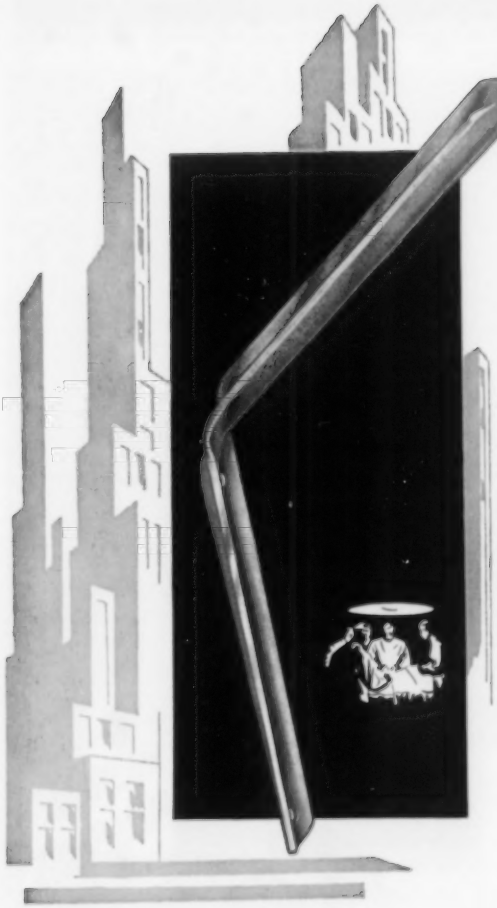
- Knuckle bender splint
- Radial palsy splint
- Finger extension splint, etc.
- Hand Drill w/Jacobs chuck
- Tendon stripper set
- Gig pull-out suture and

**other special instruments for bone and joint surgery**

*▶ Write for catalogue — postage prepaid ◀*

## H. WENIGER

*Established 1907*
***New Address***
**70-12th Street, San Francisco 3, Cal.**



**STRUCTURALLY SOUND**

**SMo**

TYPE 316

NEUFELD FEMORAL NAIL PLATES

have been engineered to provide maximum strength at the bend. Available in either Neutrilium (cobalt alloy) or type 316 stainless steel with screws of identical metals . . . The Neufeld nail is the choice of careful, discriminating orthopedic surgeons.

Ask your Surgical Supply Dealer or
write for additional technical information

**MEDICAL RESEARCH SPECIALTIES**
**Loma Linda, California**



In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

# MEDITRON'S NEW

# EMG MUSCLE TRAINER

*. . . A "must" for the physician with patients undergoing muscle rehabilitation.*

This miniaturized EMG with loudspeaker output detects clinically invisible muscle action potentials, keeps patient exercising right muscle, speeds rehabilitation at minimum cost. Easily carried by shoulder strap or belt.

**Write Dept. B for literature and prices. Quick delivery.**

THE MEDITRON COMPANY

A Division of Crescent Engineering & Research Company

5440 NORTH PECK ROAD • EL MONTE • CALIFORNIA

*A New Quarterly*

## ACTA CHIRURGIAE PLASTICAE

introduces the work of plastic surgeons in the People's Democracies.

The journal is under the editorship of the Czechoslovak Association of Plastic Surgeons, assisted by an editorial board of specialists from the URSS, China and other Eastern European countries.

The journal is open to original contributions on all aspects of plastic surgery from all over the world. It is published in English but will also publish articles in French and German.

For information about contributions write M. Dobrkovsky, M.D., Secretary, Acta Chirurgiae Plasticae, 63 Legerova, Praha 2, Czechoslovakia.

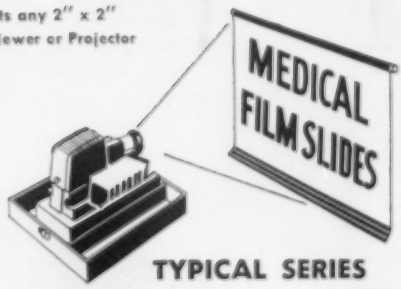
ACTA CHIRURGIAE PLASTICAE

Established 1960. Published quarterly. Each issue, 80 pages, 6¾ x 9½ inches, illustrated. Subscription price $3.20 or equivalent in any currency.

Address orders to:

**ARTIA, 30 Smecky, Praha 1, Czechoslovakia**

**Fits any 2″ x 2″ Viewer or Projector**




## TYPICAL SERIES

6 **Fractures of the Ankle** . . . . . 50 Slides
Ravenswood Hospital, Chicago, Ill.

6-4A **Bone Tumors** . . . . . 53 Slides

6-4B **Bone Tumors** (Continued from Series 6-4A) . . . 53 Slides
H. M. Stauffer, M.D., J. R. Moore, M.D., E. E. Christensen, M.D., Temple University Hospital.

6-5 **Low Back Pain** . . . . . 60 Slides
by Donald S. Miller, M.D., Chicago Medical School, Cook County Hosp., Chicago.

10-1 **Rheumatoid Arthritis Gout** . . . . . 49 Slides

10-2 **Neurogenic Arthropathy Gauchers Disease Ochronosis** . . . . . 49 Slides

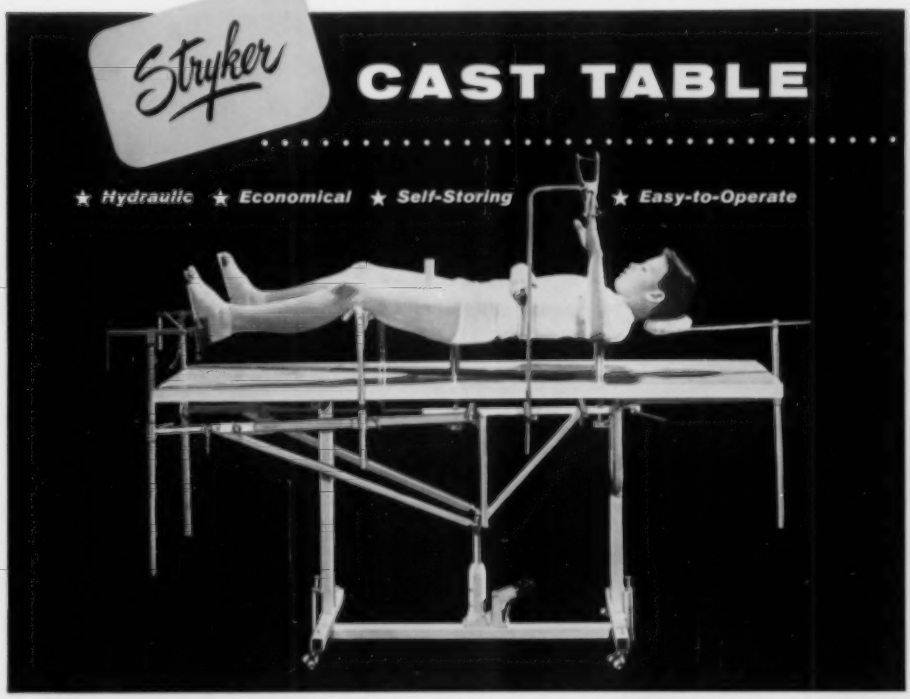
10-3 **Hemophilia Avascular Necrosis Caisson Disease in Bone** . . . . . 50 Slides
by Henry K. Taylor, M.D., Dept. Radiology, Goldwater Memorial Hospital, New York, N. Y.

**ORDER DIRECT** OR WRITE for complete description of above series, and catalog of others that are available.

Price per series . . . . . $16.50

MXRR **MEDICAL FILM SLIDE DIVISION**
MICRO X-RAY RECORDER, INC.
3755 W. Lawrence • Chicago 25, Illinois

## The NEW All-Purpose . . .



Now! A table designed specifically for all types of cast applications – body jackets, hip spicas, long and short leg casts, scoliosis casts, arm casts of all kinds. This economical, easy to set-up table simplifies plaster work, too. After positioning, the patient is hydraulically lifted for easy access to all body areas.

Padded top, adjustable knee holder rods and head rest make the table comfortable even for unanesthetized patients. Basic accessories store in position underneath. And when not used for cast applications, the Stryker Cast Table serves as an examining table. Write for full information or ask your dealer for a demonstration of the new Stryker Cast Table. You'll like its low cost, as well as its many advantages.

***PLUS THESE EXCLUSIVE EXTRAS:***

***Heel and sole plate*** separate and pull out, after plaster is wrapped around foot. Leg and knee, in place, can be moved laterally as required.

***Simplified toe and finger clamps*** hold the extremity for you with no more pressure than you would hold it yourself.

***Floor stops*** stabilize the table, prevent movement.

***Sacral and shoulder plate*** knobs secure and release the plates from below.

**Unit cost $690.00**

Stryker
SURGICAL AND HOSPITAL EQUIPMENT
Orthopedic Frame Company
420 ALCOTT STREET • KALAMAZOO, MICHIGAN

## ARTHRITIC DISORDERS

## RESPONSIVE TO TRIAMCINOLONE

"In all but two of the [17] patients the arthritis was better controlled by triamcinolone [Kenacort] therapy than any previous treatment with either steroids or other measures."*

■ enhanced anti-inflammatory, antirheumatic, antiallergic effects ■ far less gastrointestinal distress ■ may be of value when other corticoids have failed ■ virtually no mood changes, edema, sodium or water retention, or secondary hypertension

**Supply:** Scored tablets of 1 mg., 2 mg. and 4 mg. Syrup, 120 cc. bottles, each 5 cc. teaspoonful containing 5.1 mg. triamcinolone diacetate providing 4 mg. triamcinolone.

*Hollander, J. L.; Brown, E. M., Jr.; Jessar, R. A.; Udell, L.; Cooperband, S.; and Smukler, N. M.: Arth. & Rheum. 2:513 (Dec.) 1959.

For full information, see your Squibb Product Reference or Product Brief. "KENACORT"® IS A SQUIBB TRADEMARK.

**Kenacort** Squibb Triamcinolone

SQUIBB

Squibb Quality—the Priceless Ingredient

# SABEL'S

**BASIC SHOES**

TRADE MARK REG. U. S. PAT. OFF.

offers you the

# COMPLETE

## BASIC SHOE PROGRAM

From basics to highly specialized footwear, Sabel covers the field.

Shoes made on scientifically designed lasts that have been developed through direct contact with doctors and hospitals across the country . . . shoes that accept corrective measures, yet retain style features . . . shoes for boys and young men . . . surgical boots for post-operative cases for men and boys.

Sabel has the COMPLETE shoe program, all styles carried in stock for immediate delivery . . . plus 35 years of experience in the basic shoe business.

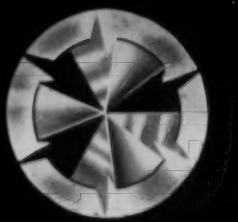
No. 772 Tan Calf
No. 672 Black Calf

No. 870 Tan Calf
No. 653 Black Calf

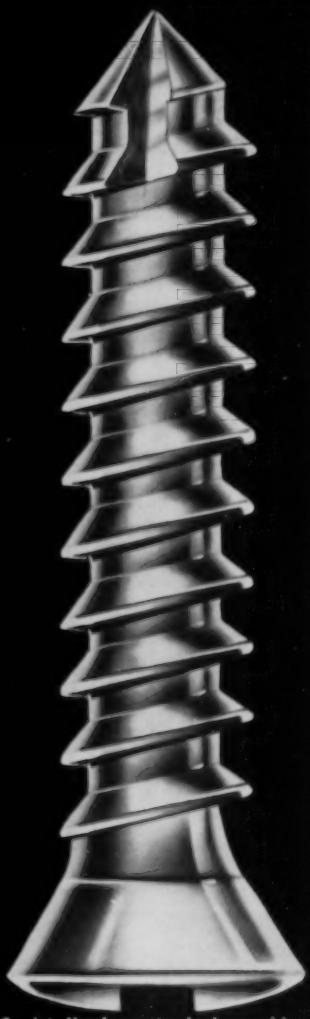
*Manufactured exclusively by*

C. H. ALDEN SHOE CO.

I. SABEL Inc., 1207 Chestnut St., Philadelphia, Pa.



Bechtol Radial Fluted Point



Cruciate Head uses standard screwdriver

# NEW Richards BONE SCREW

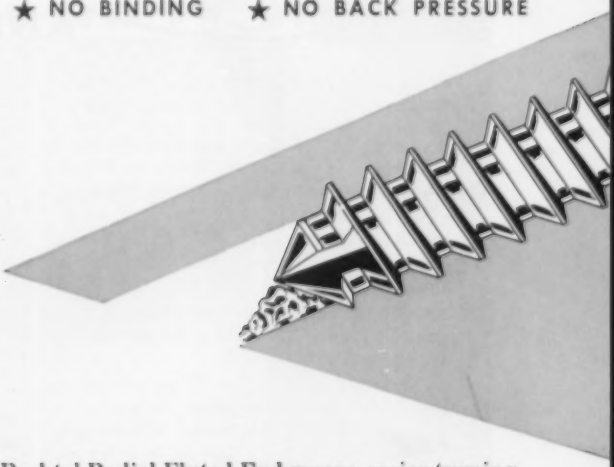
(SMO Stainless)

*with Bechtol Radial Fluted Point*

*and buttress threads*

★ TURNS EASIER ★ HOLDS BETTER

★ NO BINDING ★ NO BACK PRESSURE



**Bechtol Radial Fluted End** means easier turning because flutes move bone crumbs ahead, prevent them from clogging threads and causing screw to bind. Tests prove 50% less torque is required.

**Buttress threads** increase screw's holding power and eliminate back pressure.

**Micrometric accuracy** in manufacture assures perfectly true shank for maximum ease of entry and greatest possible thread grip.

**No special instruments needed.** Precision-cut Cruciate Head requires standard screwdriver. Regular 7/64" diameter drill bit used. Available in standard bone screw lengths.

**Write for information.**

Richards MANUFACTURING COMPANY

756 Madison Avenue, Memphis 3, Tennessee

FOR TREATMENT OF SPASTIC CASES • CEREBRAL PALSY • STROKE • POLIO • HAND INJURIES

*General Electric Co. Silicone*

**BOUNCING PUTTY**

*As a "trial order" send $2.00 for one $2.85 jar*

does not harden
lasts indefinitely
and can be
autoclaved.

**S. R. GITTENS, *Distributor,*** 1620 Callowhill St., Phila. 30, Pa.

**PRESTON** *A Complete Line* **FOR PHYSICAL THERAPY AND REHABILITATION**

**REHABILITATION:** Bicycle Exercisers; Restorator; Walking Parallel Bars and Exercise Staircases of various designs; Posture Mirrors; Gym Mats; Shoulder Wheels; Elgin Progressive Resistance Exercise Units; Quadriceps Boots; Dumbbells; Chest Pulley Weights; Standing (Tilt) Tables; Stryker Turning Frames and CircOlectric Bed.

**HAND THERAPY DEVICES:** Complete Line of Bunnell Splints; Theraplast; Exerballs, Kanavel Table; Wrist Exercisers.

**TRACTION:** Sayre's Head Slings; Many types of Cervical and Pelvic Traction Sets; Hausted Traction-aid; Tractomatic; Varitrak.

**HYDROTHERAPY-ELECTRO THERAPY:** Whirlpools; Paraffin Baths; Hydrocollator; Teca and other Low-Volt Generators; Medcolator; Medcosonlator; Infrared Lamps; Birtcher Ultrasonic Generators and Diathermy.

Walkers and Walking Aids for every need; Wheelchairs; Commodes; Hydraulic Patient Lifters; Largest selection of Crutches and Canes; Treatment Tables; Self-Help Devices for the Handicapped.

***THE PRESTON CATALOG NO. 1065***

- Topically organized for your convenience in ordering all your requirements from one dependable source. Includes over 2,500 items — the most complete Ordering Guide in the field.
- To assure you of complete quality control and prevent substitution, Preston maintains a policy of selling only directly to the profession. We do not sell through dealers.

*Requests for Catalog should be sent on your letterhead to*
J. A. Preston Corp., Dept. B.

We supply *ALL EQUIPMENT* for setting up a complete Rehabilitation Program. Suggested layouts and equipment lists are available to you through *OUR FREE PLANNING SERVICE.*

**J. A. PRESTON CORP. 71 FIFTH AVENUE, NEW YORK 3, N. Y.**

*For Congenital Dislocation of the Hip—**ORDER***

**FREJKA**
**ABDUCTION PILLOW SPLINTS**

*with the new Wet-Proof pillow*

*3 SIZES:*
*Small*—6" pillow splint (up to 4 months)
*Medium*—9" pillow splint (4 to 8 months)
*Large*—12" pillow splint (over 8 months)
Available in Pink, Yellow & White

PHONE—Midway 4-6874

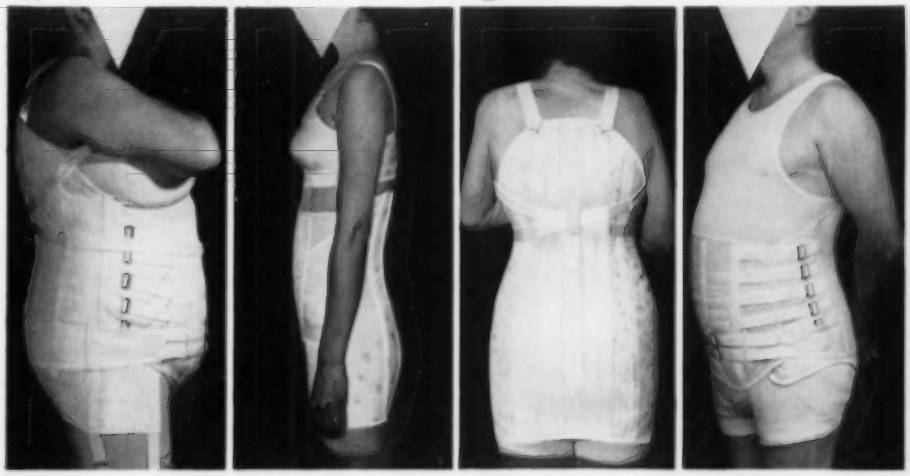
**MINNESOTA ORTHOPEDIC SERVICES**
1963 Carl Street St. Paul 13, Minn.

*PRICE*

With
Extra
Halter
$12.50

*POSTPAID*

# HAVE YOU EVER HAD TWO PATIENTS EXACTLY ALIKE?



## *Each Patient is an Individual*

in height, weight and overall size. Each patient is individual in what he or she needs in a support. How can a stock garment made for thousands fit *your patient?* How can a ready-made meet *specific needs* to do the work you expect it will do?

**THAT'S WHY SPENCER INDIVIDUALLY DESIGNS EACH SUPPORT FOR THE INDIVIDUAL PATIENT**

Spencer is available to you through specially trained Spencer Corsetieres. See yellow pages under "Corsets" for Corsetiere in your locality.

**Spencer®**

*individually designed supports for women, men and children*

SPENCER, INCORPORATED • NEW HAVEN 7, CONN.




In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

Dear Subscriber:

There is so much "family feeling" between The Journal and its subscribers that we are going to ask your help in a family problem.

We maintain our own subscription records. Every new subscription, renewal, change of address, order for back issues, inquiry, and complaint goes through the hands of a staff who almost know the subscriber files by heart. This is perhaps old-fashioned but we believe it results in better service than would any impersonal, mechanized system.

The natural busy time for the subscription department is the end of the year because most renewals start in January. This is right and proper.

This is our sad story —

The peak load of the subscription department continues through January, February, March and into April because of the *extra* work caused by renewals that come in late, that is, that are received after an issue has been missed. It takes more than three times as much time and bookkeeping to take a name off the lists and put it back as it does to record a prompt renewal. It is also frustrating work because you undo on Tuesday what you did on Monday.

Please send your renewal check early!

*Thank you*

1962 Subscription Prices

## The Journal of Bone and Joint Surgery

**American Volume $14.50**

*Eight Issues*

| | |
|---|---|
| January | July |
| March | September |
| April | October |
| June | December |

**British Volume $7.50**

*Four Issues*

| | |
|---|---|
| February | August |
| May | November |

**Both Volumes $22.00**

*Twelve Issues*

**All Single Issues $3.00**
**All Back Issues $3.00**

Subscriptions and Renewals to Both Volumes may be sent to either

**The Journal of**
**Bone and Joint Surgery**
**8 The Fenway**
**Boston 15, Massachusetts**

*or*

**The British Society of**
**Bone and Joint Surgery**
**82 Portland Place**
**London W.1, England**

---

***Sterling prices***

**American Volume £5.4.0**
**British Volume £2.13.6**



In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

**THE RUTH JACKSON COLLAR**

The Ruth Jackson collar, providing maximum occipital support, will maintain, with a high degree of comfort, the flexed position with chin tucked in, recommended by Ruth Jackson, M.D., F.A.C.S., in her book "The Cervical Syndrome."

"Collars or braces should be designed to hold the neck in the optimum position for healing . . . This position must be with the neck straight and the chin 'tucked in'. Braces which hold the neck in hyperextension are completely wrong in principle . . ."

THE CERVICAL SYNDROME by Ruth Jackson, B.A., M.D., F.A.C.S., publisher Charles C Thomas, Springfield, Ill.

**THE EXO-STATIC COLLAR**

**(completely redesigned)**

The Exo-Static collar, while it may be adjusted for full extension, may also be lowered to a point of slight flexion and provides stabilized support, not only to the chin, but laterally and to the occiput, *automatically adjusting to the proper occipital height corresponding to the extension required.*

**FLORIDA MANUFACTURING CORPORATION**

**BOX 449 • DAYTONA BEACH, FLORIDA**

*Reprint from Chapter on Treatment in "Cervical Syndrome" available on request*


## *List of Advertisers*

SEPTEMBER 1961


| | PAGE |
|---|---|
| Aireloom Bedding Company | 20 |
| C. H. Alden Shoe Company | 21 |
| American Sterilizer Company | 18 |
| Artia | 48 |
| Austenal Company | 24, 25 |
| Bauer & Black, Division of the Kendall Company | 6, 7, 45 |
| Berivon Company | 38, 39 |
| Bowen & Company, Inc. | 12 |
| S. H. Camp and Company | 26 |
| G. W. Chesbrough Co. | 33 |
| Gilbert Hyde Chick Company | 44 |
| The Collison Surgical Engineering Company | 9 |
| DePuy Manufacturing Company, Inc. | 28 |
| Eastman Kodak Company | 42 |
| Florida Brace Corporation | 23 |
| Florida Manufacturing Corporation | 55 |
| S. R. Gittens | 52 |
| Hack Shoe Company | 30 |
| J. E. Hanger, Inc. | 41 |
| Herbst Shoe Manufacturing Company | 43 |
| House of Bidwell, Inc. | 44 |
| Lederle Laboratories, Division of American Cyanamid Company | 34, 35 |
| M. J. Markell Shoe Company, Inc. | 8 |
| Medic Shoe Manufacturers, Inc. | 46 |
| Medical Research Specialties | 47 |
| The Meditron Company | 48 |
| Merck Sharp & Dohme, Division of Merck & Co., Inc. | 40 |
| Micro X-Ray Recorder, Inc. | 48 |
| Miller Brace Co. | 44 |
| Minnesota Orthopedic Services | 52 |
| V. Mueller & Co. | 32 |
| Orthopedic Equipment Co. | 37 |
| Orthopedic Frame Company | 15, 49 |
| J. A. Preston Corp. | 52 |
| Richards Manufacturing Company | 19, 51 |
| Roche Laboratories, Division of Hoffman-La Roche, Inc. | 13 |
| Zack Rogers Associates, Inc. | 31 |
| I. Sabel, Inc. | 50 |
| Chas. A. Schmidt Surgical Instrument Company | 36 |
| Sealy, Inc. | 14 |
| J. Sklar Manufacturing Co. | 22 |
| Spencer, Incorporated | 53 |
| E. R. Squibb & Sons | 50 |
| M. M. Teare Co., Inc. | 46 |
| Truform Anatomical Supports | 27 |
| Wallace Laboratories | 29 |
| H. Weniger | 46 |
| Wright Manufacturing Company | 4, 5 |
| Wyeth Laboratories | 10, 11 |
| Zimmer Manufacturing Company | 16, 17 |




In answering advertisements, please mention *The Journal of Bone and Joint Surgery.*

## ADDRESSES OF CONTRIBUTORS

### SEPTEMBER 1961


KARL S. ALFRED, M.D., 10515 Carnegie Avenue, Cleveland, Ohio

ROBERT W. BAILEY, M.D., 1405 East Ann Street, Ann Arbor, Michigan

MARK B. COVENTRY, M.D., Mayo Clinic, Rochester, Minnesota

RICHARD F. FOLLIS, M.D., Armed Forces Institute of Pathology, Washington 25, D. C.

AVRUM FROIMSOM, M.D., The Presbyterian Hospital, 622 West 68th Street, New York 32, N. Y.

K. GEORGE, M.D., 231 West Wisconsin Avenue, Milwaukee 3, Wisconsin

B. DAVID GRANT, M.B., F.R.C.S. (EDIN.), 1936 Spruce Street, Philadelphia 3, Pennsylvania

KINGSBURY G. HEIPLE, M.D., 2065 Adelbert Road, Cleveland 6, Ohio

JOSEPH M. JANES, M.D., Mayo Clinic, Rochester, Minnesota

C. L. JEANNOPOULOS, M.D., 44 West 77th Street, New York, N. Y.

A. D. JOHNSTON, M.D., Hospital for Joint Diseases, Madison Avenue, New York 35, N. Y.

PATRICK J. KELLY, M.D., Mayo Clinic, Rochester, Minnesota

SHAMSHER A. K. KHERA, M.B., B.S., Children's Hospital, Winnipeg Manitoba, Canada

JOHN P. KIM, M.D., Regina General Hospital, Regina, Saskatchewan, Canada

EDWARD O. LEVENTEN, M.D., New York State Rehabilitation Hospital, West Haverstraw, New York

DONALD B. LUCAS, M.D., University of California, San Francisco 22, California

GEORGE MIYAKAWA, M.D., 1200 Quarrier Street, Charleston 1, West Virginia

WILLIAM R. MURRAY, M.D., University of California, San Francisco 22, California

LOWELL F. A. PETERSON, M.D., Mayo Clinic, Rochester, Minnesota

J. RIPPSTEIN, M.D., 21 Champ Rond, Lausanne, Switzerland

CARTER R. ROWE, M.D., 275 Charles Street, Boston 14, Massachusetts

DAVID B. STEVENS, M.D., 304 South Limestone, Lexington, Kentucky

CHARLES F. WOODHOUSE, M.D., 25 East Washington Street, Chicago 2, Illinois